CHAPTER 12

PO 331 – DESCRIBE PRINCIPLES OF FLIGHT

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 1

EO M331.01 – DESCRIBE AIRCRAFT STABILITY

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Set up the four stations as described in Annex A.

Create slide of Annex B.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An in-class activity was chosen for TP 1 as it is an interactive way to introduce aircraft stability.

An interactive lecture was chosen for TPs 2–5 to review axes of rotation and introduce stability about the axes.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have described aircraft stability.

IMPORTANCE

It is important for cadets to describe aircraft stability so that they understand why aircraft are designed with certain features. Cadets will also understand how an aircraft will react when flying through turbulent weather or when it is put through aggressive manoeuvres.

Teaching Point 1	**Demonstrate the Characteristics of Stability**
Time: 15 min	Method: In-Class Activity

CHARACTERISTICS OF STABILITY

Stability. The tendency of an aircraft in flight to remain in straight, level, upright flight and to return to this attitude, if displaced, without corrective action by the pilot.

Static Stability. The initial tendency of an aircraft to return to its original attitude, if displaced.

Dynamic Stability. The overall tendency of an aircraft to return to its original attitude.

Positive Stability. The aircraft is able to return to its original attitude without any corrective measure.

Neutral Stability. The aircraft will remain in the new attitude of flight after being displaced, neither returning to its original attitude, nor continuing to move away.

Negative Stability. The aircraft will continue moving away from its original attitude after being displaced.

ACTIVITY

Time: 10 min

OBJECTIVE

The objective of this activity is to provide a tactile method of illustrating the different types of aircraft stability.

RESOURCES

- Tennis ball,
- Three marbles,
- Table,
- Tape, and
- Two bowls.

ACTIVITY LAYOUT

Set up four stations IAW Annex A.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into four groups of equal size.
2. Assign each group to a station.
3. Have each group perform the activity at each station.
4. After the cadets have been to all stations, ask the cadets what they observed.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 1

The cadets' participation in the stability activity will serve as confirmation of this TP.

Teaching Point 2 **Review the Axes of an Aircraft**

Time: 10 min Method: Interactive Lecture

AXES OF THE AIRCRAFT

Present the slide located at Annex B to the cadets.

Demonstrate each axis with the model aircraft.

Each axis is an imaginary straight line which runs through the aircraft in a particular direction. All three axes intersect at the centre of gravity.

Ask the cadets what the three axes of an aircraft are.

Longitudinal Axis and Roll

This axis runs the length of the aircraft from the tip of the nose to the end of the empennage. Movement around this axis is roll.

Ask the cadets which control surface controls roll.

Lateral Axis and Pitch

This axis runs through the aircrafts' wings, from wing tip to wing tip. Movement around this axis is pitch.

Ask the cadets which control surface controls pitch.

Normal (Vertical) Axis and Yaw

This axis runs through the aircraft vertically top to bottom. Movement about this axis is yaw.

Ask the cadets which control surface controls yaw.

Have the cadets make a paper airplane, marking each of the axes. Have them hold their airplanes in the air while you call out a movement (eg, roll) which they will demonstrate individually using their airplanes.

CONFIRMATION OF TEACHING POINT 2

The cadets' participation in the paper airplane activity will serve as the confirmation of this lesson.

Teaching Point 3	**Explain Longitudinal Stability**
Time: 10 min	Method: Interactive Lecture

LONGITUDINAL STABILITY

Longitudinal stability is stability around the lateral axis and is known as pitch stability. To achieve longitudinal stability, aircraft are designed to be nose heavy if loaded correctly.

Two principle factors influence longitudinal stability:

- the horizontal stabilizer, and
- the centre of gravity.

The Effects of the Horizontal Stabilizer

The horizontal stabilizer is located at the tail end of the aircraft. Its function is similar to a counterweight at the end of a lever. When the nose of the aircraft is pushed up, this will force the tail down. Since the stabilizer now meets the airflow at a higher angle of attack, it will now produce more lift. This extra lift will counter the initial disturbance.

Use the model airplane to demonstrate the effects of the horizontal stabilizer.

The Effects of the Centre of Gravity

The centre of gravity is an important factor in aircraft stability. Every aircraft has a naturally occurring centre of gravity which is inherent in its design. As the aircraft is loaded, the position of the centre of gravity can change. If this change is drastic, it can have an adverse affect on the stability of an aircraft.

Use the model airplane to demonstrate a forward centre of gravity.

If the centre of gravity is too far forward, it will produce a nose-down tendency. This will force the pilot to use excessive back pressure on the controls to maintain normal flight. If left uncorrected, the aircraft will speed up and lose altitude.

If the centre of gravity is too far aft, it will produce a nose-up tendency. This will force the pilot to use excessive forward pressure on the controls to maintain normal flight. Uncorrected, the aircraft will slow down and eventually stall.

Use the model airplane to demonstrate an aft centre of gravity.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. What is longitudinal stability?

Q2. What does the horizontal stabilizer act like?

Q3. What is the danger of an aft centre of gravity?

ANTICIPATED ANSWERS

A1. Stability around the lateral axis.

A2. A counterweight at the end of a lever.

A3. Stall.

Teaching Point 4	**Explain Lateral Stability**
Time: 10 min	Method: Interactive Lecture

LATERAL STABILITY

Lateral stability is stability around the longitudinal axis and is called roll stability. To achieve lateral stability certain design features are built into the aircraft. Three of these design features are:

- dihedral,
- sweepback, and
- keel effect.

The Effects of Dihedral and Anhedral

Dihedral is the angle that the wings make with the horizontal plane. As one looks at an aircraft from the front, the wings will slowly angle away from the ground so that the wing tip is higher than the wing root.

This assists the aircraft in maintaining lateral stability by changing the angle that the leading edge makes with the airflow.

When an aircraft with dihedral wings is forced in to a side-slipping motion, the down-going wing will meet the airflow at a right angle. This will increase the lift produced on that wing, forcing it back into place.

Use the model airplane to demonstrate dihedral.

Some aircraft have been designed with a negative dihedral, also known as anhedral. Anhedral acts opposite to dihedral, creating less stability. Usually found in aircraft with both sweepback and keel effect.

The Effects of Sweepback

Similar to the dihedral, sweepback is a design feature where the wings sweep back instead of protruding straight out from the fuselage.

This assists the aircraft in maintaining lateral stability by changing the angle that the leading edge makes with the airflow.

When an aircraft with sweepback is forced into a slipping motion, the down going wing will meet the airflow at a right angle. This will increase the lift produced by that wing forcing it back into place.

Use the model airplane to demonstrate sweepback.

Keel Effect

While dihedral and sweepback are usually found on low-wing aircraft, high-wing aircraft have stability built-in. Since the bulk of the aircraft is below the plane of the wings, it acts as a keel. When a wing is forced up by a disturbance, the fuselage acts like a pendulum swinging the aircraft back into position.

Use the model airplane to demonstrate keel effect.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS

Q1. What is lateral stability?

Q2. What are three design features which provide lateral stability?

Q3. How does keel effect work?

ANTICIPATED ANSWERS

A1. Lateral stability is stability around the longitudinal axis.

A2. Dihedral, sweepback, and keel effect.

A3. When a wing is forced up by a disturbance, the fuselage acts like a pendulum swinging the aircraft back into position.

Teaching Point 5	Explain Directional Stability and the Effects of the Fin
Time: 5 min	Method: Interactive Lecture

DIRECTIONAL STABILITY

Directional stability is stability around the vertical or normal axis. The principle factor influencing directional stability is the vertical tail surface, or fin.

The Effects of the Fin

Aircraft, specifically airplanes, have a tendency of always flying head-on into the relative airflow. This tendency, called weather vaning, is a direct result of the vertical tail fin. If the aircraft yaws away from its course, the airflow strikes the fin from the side, forcing it back into position.

This will only work if the side area of the aircraft is greater aft of the centre of gravity than the area forward of the centre of gravity.

Use the model airplane to demonstrate the effects of the fin.

CONFIRMATION OF TEACHING POINT 5

QUESTIONS

Q1. What is directional stability?

Q2. What is the principle factor influencing directional stability?

Q3. What is the effect of the fin?

ANTICIPATED ANSWERS

A1. Directional stability is stability around the vertical or normal axis.

A2. The principle factor influencing directional stability is the vertical tail surface, or fin.

A3. If the airplane yaws away from its course, the airflow strikes the fin from the side, forcing it back into position.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. What is dynamic stability?

Q2. What is the danger of an aft centre of gravity?

Q3. What are three design features which provide lateral stability?

ANTICIPATED ANSWERS

A1. The overall tendency of an aircraft to return to its original position.

A2. Stall.

A3. Dihedral, sweepback, and keel effect.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

This EO is assessed IAW Chapter 3, Annex B, Aviation Subjects–Combined Assessment PC.

CLOSING STATEMENT

Aircraft, airplanes in particular, require a lot of stability in order to operate safely. All airplanes have stability designed into them. Commercial and private airplanes tend to have positive stability, while military fighters tend to have neutral or negative stability.

INSTRUCTOR NOTES/REMARKS

If EO C331.01 (Review Principles of Flight, Section 2) is chosen as a complementary period, it should be scheduled prior to this EO.

When developing activities for the mandatory familiarization flying/elemental training day, it is recommended that the cadet be given the opportunity to identify and describe the stability of the aircraft.

REFERENCES

C3-116 (ISBN 0-9680390-5-7) MacDonald, A. F., & Peppler, I. L. (2000). *From the Ground Up: Millennium Edition*. Ottawa, ON: Aviation Publishers Co. Limited.

C3-229 (ISBN 0-521-02128-6) Abzug, M. J., & Larrabee, E. E. (2002). *Airplane Stability and Control* (Second Edition). Cambridge, England: Cambridge University Press.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 2

EO C331.01 – REVIEW PRINCIPLES OF FLIGHT

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Make copies of the handout located at Annex C for each cadet.

Make a slide of Annex C.

Bring a model airplane.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An in-class activity was chosen for this lesson as an interactive way for the cadets to review the three axes of an aircraft and control surfaces.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have reviewed principles of flight.

IMPORTANCE

It is important for cadets to review the principles of flight as a basis for learning new knowledge and skills. Comprehension of the basic principles of flight will enhance any familiarization flying activity.

Teaching Point 1 **Review the Three Axes of an Aircraft**

Time: 5 min Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is to review the three axes of an aircraft.

RESOURCES

- Handout located at Annex C,
- Slide of Annex C, and
- Overhead projector.

ACTIVITY LAYOUT

Arrange the classroom to allow for small group work.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into groups of no more than four.
2. Distribute handout to each group.
3. Have the cadets label the diagram.
4. Have a cadet from each group move to another group and cross-check their answers. Have the cadets return to their group when done.
5. Project the slide onto a screen or wall.
6. Have a representative from three of the groups label one of the axes on the projected slide.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 1

The cadets' participation in the in-class activity will serve as confirmation of this TP.

Teaching Point 2 | **As a Member of a Group, Have the Cadet Describe a Control Surface and its Effects on Attitudes and Movements**

Time: 20 min | Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is review control surfaces and their effects on attitudes and movements.

RESOURCES

- Model airplane,
- Flip chart paper, and
- Flip chart markers.

ACTIVITY LAYOUT

Arrange the classroom to allow for small group work.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into equal groups.
2. Assign each group a control surface (rudder, aileron, or elevator).
3. Have the cadets illustrate, in the fullest detail possible, the control surface assigned to their group. Allow the cadets 10 minutes to complete their illustration.
4. Have the cadets post their group's illustration on the wall. Have the cadets conduct a gallery walk for five minutes.
5. With the remaining five minutes, lead the cadets in a discussion on each of the control surfaces. Use the model airplane for demonstration purposes.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 2

The cadets' participation in the in-class activity will serve as confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' participation in the activity in TP 2 will serve as confirmation of this lesson.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

A review of principles of flight is important for understanding higher level material. Cadets who wish to pursue training in aviation must have a solid understanding of how aircraft fly.

INSTRUCTOR NOTES/REMARKS

If this complementary EO is chosen, it should be scheduled before any other EOs from this PO.

REFERENCES

C3-116 (ISBN 0-9680390-5-7) MacDonald, A. F., & Peppler, I. L. (2000). *From the Ground Up: Millennium Edition*. Ottawa, ON: Aviation Publishers Co. Limited.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 3

EO C331.02 – READ PITOT STATIC INSTRUMENTS

Total Time: 60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Photocopy the worksheets located at Annexes D, F, and H for each cadet.

Create OHPs of the answer keys located at Annexes E, G, and I.

Construct a working model of each of the pitot static instruments IAW Annex J.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for TPs 1 to 4 to introduce pitot static instruments.

An in-class activity was chosen for TP 5 as an interactive way to confirm the cadets' comprehension of pitot static instruments.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall be expected to read the airspeed indicator (ASI), altimeter, and vertical speed indicator (VSI).

IMPORTANCE

It is important for the cadets to be able to read pitot static instruments so that they are aware of what is happening in the aircraft while participating in familiarization flying or using a flight simulator.

Teaching Point 1	Explain That the Basic Instruments of an Aircraft Rely on the Pitot Source and the Static Port as Sources of Information
Time: 10 min	Method: Interactive Lecture

BASIC INSTRUMENTS OF AN AIRCRAFT

There are two main sources from which the pitot static instruments receive information. The first of these is the pitot source and the second is the static source.

Pitot and Static Sources Provide Information for the ASI

The pitot source on a light aircraft is usually a pitot tube which is attached to the nose or wing of the aircraft. The information from the pitot source goes directly to the ASI, which then translates the pressure into airspeed. Since the pitot source is facing forward, it acts as an intake for air. Therefore the faster the aircraft is moving, the greater the pressure at the pitot source, which in turn means the higher the reading on the ASI.

The ASI also receives information from the static source. This information will allow the ASI to compensate for changes in the air pressure when at different altitudes.

Static Port Provides Information for the Altimeter

The static port is a small vent on the side of the aircraft. This senses the surrounding pressure of the air and feeds it to the altimeter. The static port relies on changes in air pressure to work. For example, as the aircraft increases in altitude, the air pressure decreases. This causes the altimeter to indicate a higher altitude.

Static Port Provides Information for the VSI

The static port also provides information to the VSI. As the aircraft changes its altitude, the VSI will indicate the rate of change. This reading is based on the rate at which the surrounding air pressure is changing.

> The ASI is the only pitot static instrument which receives pressure from both sources.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. Which is the only instrument that uses the pitot source?

Q2. Where on a light aircraft is the pitot source usually located?

Q3. How does pressure affect the altimeter?

ANTICIPATED ANSWERS

A1. ASI.

A2. The pitot source is usually attached to the nose or wing.

A3. As pressure decreases, the indicated altitude on the altimeter will increase.

Teaching Point 2 | **Explain How to Read an ASI**

Time: 10 min | Method: Interactive Lecture

READ THE AIRSPEED INDICATOR (ASI)

Reading the ASI is straightforward, and is nearly the same as reading a speedometer in a car. There is one needle and it points to the speed at which the aircraft is travelling. The biggest difference between the speedometer and the ASI is that the ASI has a colour code lining the speed scale.

Each of these arcs represent a speed range for certain flying conditions. The three colours common to all ASIs are:

- green,
- yellow, and
- red.

North American Powered Parachute Federation, "Flight Instruments". Retrieved October 30, 2007, from http://www.nappf.com/nappf_flight_instruments.htm

Figure 12-3-1 Airspeed Indicator

Normal Operating Range

The green arc indicates safe and normal flying speeds. During normal flying the pilot will modify engine power and pitch attitude so that the airspeed flown is somewhere within the green arc. This does not apply for the early part of takeoff or the last part of landing, and may not apply during aerobatic manoeuvres.

Cautionary Range

The yellow arc indicates the cautionary speed range. The aircraft can fly safely at speeds in the yellow arc range, but only if manoeuvres are kept small and gentle. Aggressive manoeuvres at speeds in the yellow arc can cause structural damage to the aircraft.

Never Exceed Speed

The red line indicates the maximum speed that the aircraft should be flown at under any circumstances. If the airspeed exceeds the red line speed, then the aircraft has to be grounded and undergo a structural inspection. Exceeding the red line may cause structural damage.

Units of Measurement

When reading the ASI, it is very important to know what units of measurement are used. In most ASIs, the unit of measurement is knots indicated airspeed (KIAS). In slower aircraft ASIs may use miles per hour (mph) as the unit of measurement. The difference between the two units is that one nautical mile (used for KIAS) is 6 080 feet, whereas one statute mile is 5 280 feet.

ACTIVITY

Time: 5 min

OBJECTIVE

The objective of this activity is for the cadet to practice reading an ASI.

RESOURCES

- ASI worksheet located at Annex D, and
- OHP of the answer key located at Annex E.

ACTIVITY LAYOUT

N/A.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into pairs.
2. Distribute the ASI worksheet to each cadet.
3. Allow the cadets two to three minutes to complete the worksheet.
4. Allow the cadets two minutes to share and review answers with their partner.
5. Show the OHP of the answer key.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 2

The cadets' participation in the activity will serve as the confirmation of this TP.

Teaching Point 3	**Explain How to Read an Altimeter**
Time: 10 min	Method: Interactive Lecture

READ AN ALTIMETER

The altimeter is the instrument which tells the pilot how high above sea level (ASL) the aircraft is. In North America the altimeter measures in feet ASL.

Units of Measurement

Every altimeter has at least three hands: one long, one short and stubby, and one long and thin with a triangle on the end.

North American Powered Parachute Federation, "Flight Instruments". Retrieved October 30, 2007, from http://www.nappf.com/nappf_flight_instruments.htm

Figure 12-3-2 The Altimeter

The long hand measures altitude in hundreds of feet ASL. This is the fastest moving hand of the three and a change in altitude will make it move.

The short hand measures altitude in thousands of feet ASL. This hand moves slowly as the altitude changes. Every time the long hand goes through a 360-degree rotation, the short hand will move to the next number on the dial.

The third hand is the thinnest and the slowest moving. It measures altitude in tens of thousands of feet ASL. As the short hand goes through a 360-degree rotation the short hand will move to the next number indicating ten thousand, twenty thousand, thirty thousand feet ASL and so on.

Pressure Sub-Scale

On the right hand side of the altimeter, there is a sub-scale. This sub-scale is used to adjust the altimeter to account for differences in the pressure of the surrounding air. The altimeter is sensitive to air pressure, and readings will change as pressure changes. Pilots have to be diligent and ensure that the sub-scale is set properly.

Field Elevation Versus Pressure Altitude

The sub-scale relies on pressure altitude to calibrate the altimeter. Pressure altitude is the perceived altitude based on the current air pressure. If this information is not available, pilots can set their altimeter to the elevation of the airfield, called field elevation. This will set the altimeter sub-scale to the proper reading.

Height Above Sea Level (ASL)/Above Ground Level (AGL)

The altimeter is designed to be used relative to sea level and is used on long flights where the ground changes in elevation. When arriving and departing an airport, all procedures are followed relative to the height above the ground. This is known as height AGL.

Reading an altimeter is very similar to reading an analog clock. Every time the second hand passes 12, the minute hand advances to the next minute. Every time the minute hand passes 12, the hour hand advances to the next hour. The altimeter works the same way.

ACTIVITY

Time: 5 min

OBJECTIVE

The objective of this activity is to allow the cadet to practice reading an altimeter.

RESOURCES

- Altimeter worksheet located at Annex F, and
- OHP of the answer key located at Annex G.

ACTIVITY LAYOUT

N/A.

ACTIVITY INSTRUCTIONS

1. Distribute the altimeter worksheet to each cadet.
2. Using the first two questions as examples, show the cadets how to read the altimeter.
3. Have the cadets complete the worksheet with a partner.
4. Show the OHP of the answer key.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 3

The cadets' participation in the activity will serve as the confirmation of this TP.

Teaching Point 4	**Explain How to Read a VSI**
Time: 10 min	Method: Interactive Lecture

READ A VERTICAL SPEED INDICATOR (VSI)

The VSI is an instrument, which measures the rate at which the aircraft is changing altitude.

Units of Measurement

The VSI is different than the altimeter in that the altimeter measures the exact height ASL, whereas the VSI measures how fast the aircraft is gaining or losing altitude in feet per minute.

Positive/Negative Rates of Climb

The VSI is divided in half, top and bottom. Both halves are measured in increments of 100 feet, represented by the numbers 1–10 or 1–20. When the needle on the VSI is pointed to the number 1, it means 100 feet per minute. The top half is a positive rate of change in altitude or rate of climb, while the bottom half is a negative rate of change in altitude or rate of descent.

North American Powered Parachute Federation, "Flight Instruments". Retrieved October 30, 2007, from http://www.nappf.com/nappf_flight_instruments.htm

Figure 12-3-3 The Vertical Speed Indicator

ACTIVITY

Time: 5 min

OBJECTIVE

The objective of this activity is to allow the cadet to practice reading the VSI.

RESOURCES

- VSI worksheet located at Annex H, and
- OHP of the answer key located at Annex I.

ACTIVITY LAYOUT

N/A.

ACTIVITY INSTRUCTIONS

1. Distribute VSI worksheet to each cadet.
2. Have the cadets to complete the worksheet.
3. Show the OHP of the answer key.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 4

The cadets' participation in the activity will serve as the confirmation of this TP.

Teaching Point 5 **Have the Cadet Read Pitot Static Instruments**

Time: 10 min Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is for the cadet to practice reading pitot static instruments.

RESOURCES

- One working model of each of the pitot static instruments, including:
  - ASI,
  - Altimeter, and
  - VSI; and
- Questions located at Annex K.

ACTIVITY LAYOUT

N/A.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into two teams.
2. Set one model at a time (in no particular order) and allow each team five seconds to read the instrument.
3. Alternate which team answers. The teams get one point for every correct answer that they give.
4. If a team cannot correctly answer the question within five seconds then the other team can steal the point.
5. The team which answers the most questions correctly wins.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 5

The cadets' participation in the activity will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' participation in each of the activities will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Knowing how to read the pitot static instruments is essential in order to fly an aircraft. Even if a pilot is not flying under IFR conditions, these three instruments are required in order to safely operate the aircraft. They also allow the pilot to coordinate with other pilots and ATS to ensure traffic avoidance or to fly circuits at an aerodrome.

INSTRUCTOR NOTES/REMARKS

N/A.

REFERENCES

C3-116 (ISBN 0-9680390-5-7) MacDonald, A. F., & Peppler, I. L. (2000). *From the Ground Up: Millennium Edition*. Ottawa, ON: Aviation Publishers Co. Limited.

C3-139 (ISBN 0-7715511-5-0) Transport Canada. (1999). *Flight Training Manual: 4th Edition Revised*. Ottawa, ON: Transport Canada.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 4

EO C331.03 – IDENTIFY ASPECTS OF HELICOPTER AERODYNAMICS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of Annexes L and M.

Bring a model helicopter to class. If possible use a radio-controlled helicopter to illustrate helicopter aerodynamics.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to introduce the cadets to aspects of helicopter aerodynamics.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall be expected to identify aspects of helicopter aerodynamics.

IMPORTANCE

It is important for cadets to identify aspects of helicopter aerodynamics so that they can appreciate the differences between airplanes and helicopters.

Teaching Point 1 | **Describe the Main Rotor of a Helicopter**

Time: 15 min | Method: Interactive Lecture

THE MAIN ROTOR OF A HELICOPTER

Helicopters, like airplanes, have airfoils. Unlike airplanes, which have fixed airfoils (wings), the airfoils of a helicopter are not in a fixed position. The airfoils on a helicopter are called rotor blades, which are attached to a rotating point on the top of the helicopter's airframe. The whole assembly is referred to as the main rotor or rotor system.

The terms "fixed wing" (airplane) and "rotary wing" (helicopter) are derived from the physical differences between airplane and helicopter airfoils.

Use the model of the helicopter to illustrate each of the following points. If possible, a radio-controlled helicopter model should be used as it will dynamically illustrate the concepts of rotor thrust and rotor drag.

Rotor Systems

The rotor systems of a helicopter incorporate many parts. Three of the basic parts are:

- the rotor blades,
- the rotor head, and
- the drive shaft.

The rotor blades are attached to the rotor head. The rotor head sits on top of the drive shaft. As the drive shaft spins, it moves the blades through the air.

As the blades spin, they act like the wings of an airplane. The shape of the rotor blade is symmetrical, meaning that the top of the blade is shaped the same as the bottom of the blade. As each blade passes through the air, the airflow over the blade creates lift using the same principles of a wing.

In order for a helicopter to move in a horizontal direction, the rotor system must be angled in the direction of travel. This changes the angle of the plane in which the blades rotate, and the rotor blades act the same as propellers.

Flying a helicopter is complicated. Once the angle of the plane of rotation has been changed, the amount of lift being produced will no longer be enough to maintain the helicopter's altitude. The pilot must apply more power in order to counteract this. The total lift force required to maintain the helicopter's altitude and forward motion is referred to as total rotor thrust.

Rotor Drag

Rotor drag is the opposite of rotor thrust. It is commonly known as torque, and acts opposite to the direction that each blade travels. Rotor drag attempts to slow down the rotation of the blades and an increase in engine power is required to maintain the speed of the blades. If the force of rotor drag is stronger than the rotor thrust, then the torque causes the body of the helicopter to rotate instead of the blades.

Rotor drag should not be confused with aerodynamic drag.

> Aerodynamic drag is a force that acts on the body of the aircraft as it moves through the air. It acts opposite to thrust (see the four forces acting on an aircraft).

Factors Influencing Rotor Thrust

There are four factors that influence rotor thrust, including:

- **Air Density.** As the rotor blades pass through the air, the reaction between the air molecules and the surface of the blade produces lift. More air molecules will create a stronger reaction. One may state that more lift is produced in higher density air vice lower density air because dense air has more molecules. Air density can decrease with increases in temperature or decreases in pressure.
- **Rotor Revolutions per Minute (rpm).** An increase in rotor rpm increases the total rotor thrust, while a decrease in rotor rpm decreases the total rotor thrust.
- **Blade (Pitch) Angle.** An increase in the blade angle increases the total rotor thrust, while a decrease in the blade angle decreases the total rotor thrust. This is similar to the effects of pitch on an airplane's wings.
- **Disc Area.** Disc area is the total area in which the rotor blades rotate and is determined by the length of the rotor blades. The larger the disc area is, the higher the total rotor thrust will be. This follows the same principle with airplanes, where the larger the wing area, the more lift is produced.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. What are the three basic parts of a rotor system?

Q2. Which force acts opposite to rotor thrust?

Q3. How does disc area influence rotor thrust?

ANTICIPATED ANSWERS

A1. The rotor blades, rotor head, and drive shaft.

A2. Rotor drag.

A3. The larger the disc area is, the higher the total rotor thrust will be.

Teaching Point 2	Describe the Anti-Torque Rotor of a Helicopter
Time: 5 min	Method: Interactive Lecture

THE ANTI-TORQUE ROTOR

> Show slide of Annex L.

Location on the Airframe

The anti-torque rotor is a smaller version of the main rotor. It is mounted vertically at the end of the tail. Most helicopters have an anti-torque rotor that sits in the right side of the tail, although some designs have the anti-torque rotor mounted on the left side or built into the tail assembly.

Airforce Imagery, 2008, CH-149 Cyclone. Copyright 2006 by Sikorsky Aircraft Corporation. Retrieved April 9, 2008, from http://www.airforceimagery.forces.gc.ca/netpub/server.np?find&catalog=casimages&template=detail2_e.np&field=itemid&op=matches&value=3018&site=casimages

Figure 12-4-1 Location of Anti-Torque Rotor

Function

The function of the anti-torque rotor is to counteract the torque produced by the main rotor. Without the anti-torque rotor, the rotation of the main rotor would transfer to the airframe and rotate the airframe instead of the rotor blades. By installing the anti-torque rotor, the airframe stays relatively still while the rotor blades rotate above the airframe. The anti-torque rotor serves to control movement around the vertical axis of the helicopter.

Power Source

The anti-torque rotor receives power from the main engine through a drive shaft which runs the length of the tail assembly.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. Where is the anti-torque rotor normally located?

Q2. What are the functions of the anti-torque rotor?

Q3. How does the anti-torque rotor receive power?

ANTICIPATED ANSWERS

A1. It is mounted vertically at the end of the tail.

A2. The functions of the anti-torque rotor are to counteract the torque produced by the main rotor and to control movement around the vertical axis.

A3. The anti-torque rotor receives power from the main engine through a drive shaft, which runs the length of the tail assembly.

Teaching Point 3 — **Explain the Control Inputs of a Helicopter**

Time: 5 min — Method: Interactive Lecture

CONTROL INPUTS OF A HELICOPTER

There are three primary control inputs of a helicopter. They differ from the control inputs of an airplane in some ways, but are similar in others. The three primary control inputs are:

- collective,
- cyclic, and
- pedals.

Show slide of Annex M.

Collective

The collective is an arm lever located on the left side of the pilot's seat (in most helicopters the pilot sits on the right side of the cockpit). The collective controls the angle of attack of the rotor blades which will affect the amount of lift produced. Pulling up on the collective will increase the angle of attack, producing more lift. Pushing down on the collective will decrease the angle of attack, producing less lift.

At the end of the collective is a throttle. The throttle on a helicopter is a twist-style grip. The throttle controls the rpm of the blades. An increase in rpm will increase the amount of lift produced and the speed at which the helicopter travels.

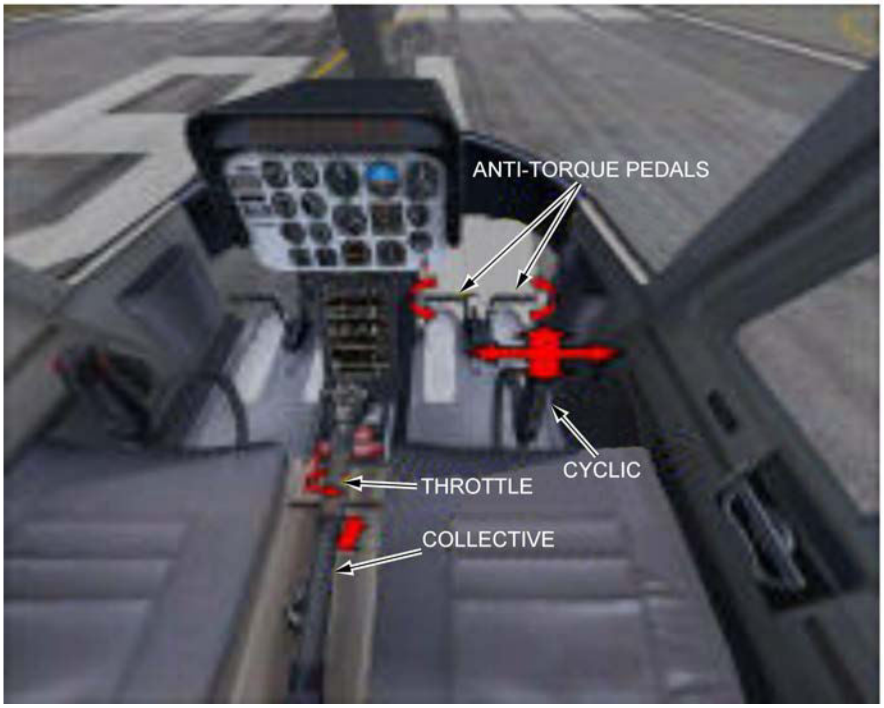
It is important to remember that the rotors act in the same way as both the wings and the propeller of an airplane. They produce the lift and the thrust. The same happens for movements forward, backward and to the right.

Cyclic

In a helicopter, the control column is known as the cyclic. The cyclic controls the angle of the plane in which the rotor blades move. Moving the cyclic left will angle the rotation of the blades left. Maintaining that angle long enough will move the helicopter to the left.

Pedals

The pedals in a helicopter cockpit are similar to rudder pedals. They control the anti-torque rotor, providing directional stability. They also control which direction the nose of the helicopter is pointed. One of the unique capabilities of a helicopter is that the nose can be pointed in a different direction than the direction of travel. This provides the helicopter increased manoeuvrability.



AVSIM Online, by S. Cartwright, 2004, Helicopter Tutorial. Copyright 2004 by AVSIM Online. Retrieved April 8, 2008, from http://www.avsim.com/pages/0604/heli/helitutorial.htm

Figure 12-4-2 Helicopter Control Inputs

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. What does the collective control?

Q2. What does the cyclic control?

Q3. What do the pedals control?

ANTICIPATED ANSWERS

A1. The angle of attack of the rotor blades.

A2. The angle of the plane in which the rotor blades move.

A3. They control the anti-torque rotor, providing directional stability. They also control which direction the nose of the helicopter is pointed.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. How do the main rotor systems produce lift?

Q2. What is the function of the anti-torque rotor?

Q3. What is one of the unique capabilities of helicopters?

ANTICIPATED ANSWERS

A1. As each blade passes through the air, the airflow over the blade creates lift using the same principles as a wing.

A2. The function of the anti-torque rotor is to counteract the torque produced by the main rotor.

A3. One of the unique capabilities of a helicopter is that the nose can be pointed in a different direction than the direction of travel.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Helicopters are flown using very different applications of Newtonian physics. Certain parts of the helicopter are similar to airplanes but have different functions. These differences make the helicopter a more manoeuvrable aircraft and more challenging to fly.

INSTRUCTOR NOTES/REMARKS

It is recommended that this EO be scheduled with EO C331.05 (Tour a Local Aviation Facility, A-CR-CCP-803/PG-001, Chapter 4, Section 13) if helicopters are present at the facility.

If the squadron has the opportunity to participate in familiarization flights in a helicopter, this EO should be conducted at that time.

REFERENCES

C3-249 (ISBN 978-1-56027-649-4) Wagtendok, W. J. (2006). *Principles of Helicopter Flight: Second US Edition*. Newcastle, WA: Aviation Supplies & Academics, Inc.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 5

EO C331.04 – DEMONSTRATE ATTITUDES AND MOVEMENTS IN A FLIGHT SIMULATOR

Total Time:	90 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create a scenario for the computer simulator IAW the manual provided with the software. The guidelines for this scenario should be using a local airport, no weather, and a starting altitude of 5 500 feet ASL.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for TPs 1 and 2 to give direction on procedures and present basic or background information about flight simulation.

A simulation was chosen for TP 3 as it is an interactive way to allow the cadet to experience attitudes and movements in a safe, controlled environment. This activity contributes to the development of principles of flight skills and knowledge in a fun and challenging setting.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall be expected to demonstrate attitudes and movements and read pitot static instruments in a flight simulator.

IMPORTANCE

It is important for cadets to apply this knowledge in a flight simulator to enhance the learning value of attitudes and movements. This will also serve as a solid foundation for any cadet who participates in flight training in the future.

Teaching Point 1 — **Explain Safety Considerations Related to the Location or Design of the Flight Simulator**

Time: 5 min — Method: Interactive Lecture

> Arrange the cadets so they can hear the safety briefing prior to using the flight simulator.

> This briefing is being conducted to pass on safety considerations for use of the flight simulator. The actual content of the briefing will vary by region and squadron based on the squadron's assets, the location of the assets, and other environmental factors. The following should be covered:
>
> - DND regulations concerning the appropriate use of computers, including:
>   - CATO 11-07 (Internet Acceptable Use – Cadet Program),
>   - DAOD 6001 (Internet),
>   - Regional Orders, and
>   - Squadron Standing Orders;
> - location of the nearest fire exit in case of fire;
> - awareness of any moving parts of the simulator; and
> - proper entry and exit techniques to avoid damage to assets.

CONFIRMATION OF TEACHING POINT 1

Confirmation of this TP will depend on the actual content covered.

Teaching Point 2 — **Explain How to Manipulate the Necessary Control Inputs and the Location of Necessary Instruments**

Time: 15 min — Method: Interactive Lecture

CONTROL COLUMN OR YOKE

> Using a control column or yoke in a flight simulator is preferable. Accordingly, the following will need to be adjusted if a control column is used instead.

The control yoke is located directly in front of the pilot in the centre of the pilot's side of the instrument panel. The control yoke is very much like the steering wheel of a car, both in look and function. The yoke is designed to move on two planes of motion.

The first plane of motion is left and right. The standard yoke will usually move to approximately 45 degrees left or right of centre when moved like a steering wheel. This motion is what controls the ailerons of the simulated airplane. To roll left, turn the wheel left. To roll right, turn the wheel right. Remember, this must be used as well as the rudder in order to properly turn the aircraft.

The control yoke also moves back and forth. The steering column of the yoke moves in and out of the main assembly. This controls the elevator of the simulated aircraft. To pitch up, pull back (towards the pilot). To pitch down, push forward (away from the pilot).

> Pitch will change your altitude, but more importantly your airspeed.

RUDDER PEDALS

On the floor of the simulator there are two pedals. If you push forward on the left pedal, the right one moves back and vice versa. These pedals control the rudder of the simulated aircraft. To yaw left, push on the left pedal. To yaw right, push on the right pedal.

> Rudder pedals move in different directions so pressure must be taken off the opposite pedal in order for the movement to take place.

LOCATION OF INSTRUMENTS

The instruments of the simulated aircraft will be displayed in front of the pilot, laid out on what is called an instrument panel. The three instruments that are of significance are the pitot static instruments: the airspeed indicator (ASI), vertical speed indicator (VSI), and altimeter. They are usually located just above the control yoke in a cluster of six instruments.

ASI. The ASI is located on the top row of the instrument panel on the far left.

VSI. The VSI is located on the bottom row of the instrument panel on the far right.

Altimeter. The altimeter is located on the top row of the instrument panel on the far right, just above the VSI.

"Design a Virtual Cockpit Instrument Panel", Ngee Ann Polytechnic, 2007. Retrieved October 31, 2007, from http://www.learnerstogether.net/avionics-project-design-problem-based-learning/56

Figure 12-5-1 Cessna Flight Instrument Panel

There is no need to go in to any detail about the other three instruments located in the diagram.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. Where is the control yoke located?

Q2. Where are the pitot static instruments located?

Q3. How is pitch controlled?

ANTICIPATED ANSWERS

A1. In front of the pilot centred on the instrument panel.

A2. Clustered together, just above the control yoke.

A3. By moving the yoke towards or away from the pilot.

Teaching Point 3 — **Supervise the Cadets as They Practice Attitudes and Movements Using the Flight Simulator**

Time: 60 min — Method: Simulation

ACTIVITY

OBJECTIVE

The objective of this activity is to allow the cadet to practice attitudes and movements and witness their effect on the pitot static instruments.

RESOURCES

- Computer flight simulator (Microsoft flight simulator, computer, control yoke, and rudder pedals), and
- Scenario using local airport, no weather, and a starting altitude of 5 500 feet ASL.

ACTIVITY LAYOUT

This will depend on the location of the simulator.

ACTIVITY INSTRUCTIONS

1. Start the simulator with the scenario created prior to the lesson.
2. Allow the cadets to take turns in the simulator, practicing attitudes and movements.
3. Each cadet should be given an equal amount of time. This means that the 60 minutes should be divided as evenly as possible by the number of cadets in the class.
4. If a cadet is quickly grasping the concepts, move on to the next cadet. This will allow some flexibility in the event a cadet does not grasp the concepts quickly.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 3

The cadets' participation in this activity will serve as confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' participation in the flight simulator, practicing attitudes and movements, will serve as confirmation of this lesson.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

It has been stated by many flight instructors that a significant difference can be seen in the skill quality of students who used a flight simulator compared to those who did not. The military is a large user of computer-based flight simulators, as are Air Canada and WestJet. Cadets are encouraged to train on flight simulators as it will enhance their preparation for future flight training.

INSTRUCTOR NOTES/REMARKS

Concurrent activities may be required based on the number of simulators available.

All staff should be familiar with the operation of the flight simulator prior to the EO. This will better prepare them to troubleshoot and instruct.

REFERENCES

C3-139 (ISBN 0-7715511-5-0) Transport Canada. (1999). *Flight Training Manual: 4th Edition Revised*. Ottawa, ON: Transport Canada.

C3-156 *Computerized Aircraft Simulation Center*. (2007). Retrieved October 2, 2007, from http://www.regions.cadets.forces.gc.ca/pac/aircad/flight/casc_lessons_e.asp.

THE FOUR STATIONS

<u>Station 1</u>: Tennis Ball – Dynamic and Static Stability

This station should be set up in an area of the classroom where there will be a six-foot (2-metre) length of unobstructed floor space. Place a piece of tape on the floor to mark the starting position. Place a tennis ball on the piece of tape.

1. Have the cadet pick up the ball to shoulder height (thus displacing it from its original position) and then drop it back on to the floor.
2. Have the cadet observe the tennis ball as it bounces.
3. The initial bounce is the static stability, while the remaining bounces reflect dynamic stability.

<u>Station 2</u>: Marble With Bowl – Positive Stability

In the centre of the table place the bowl, right-side up. Place a marble in the centre of the bowl.

1. Have the cadet push the marble with their finger to just below the lip of the bowl.
2. Allow the marble to fall back to the bottom of the bowl.
3. Observe the results.
4. The end result is that the marble will return to its original place; positive stability.

<u>Station 3</u>: Marble on Flat Level Surface – Neutral Stability

Place a marble on one end of a table.

1. Have the cadet gently push the marble towards the other end of the surface.
2. Observe the marble as it rolls and then stops.
3. The marble is now in a new position, neither moving further away nor moving back to its starting place.

<u>Station 4</u>: Marble With Bowl – Negative Stability

This station should be set up on a table. In the centre of the table, place a bowl, upside down. Place a marble on top of the bowl.

1. Have the cadet gently push the marble towards the edge of the bowl's base.
2. Watch as the marble continues to move away from its starting place. This is negative stability.
3. Have the cadets chase after the marble and replace it. Replacing the marble is not part of the demonstration of negative stability.

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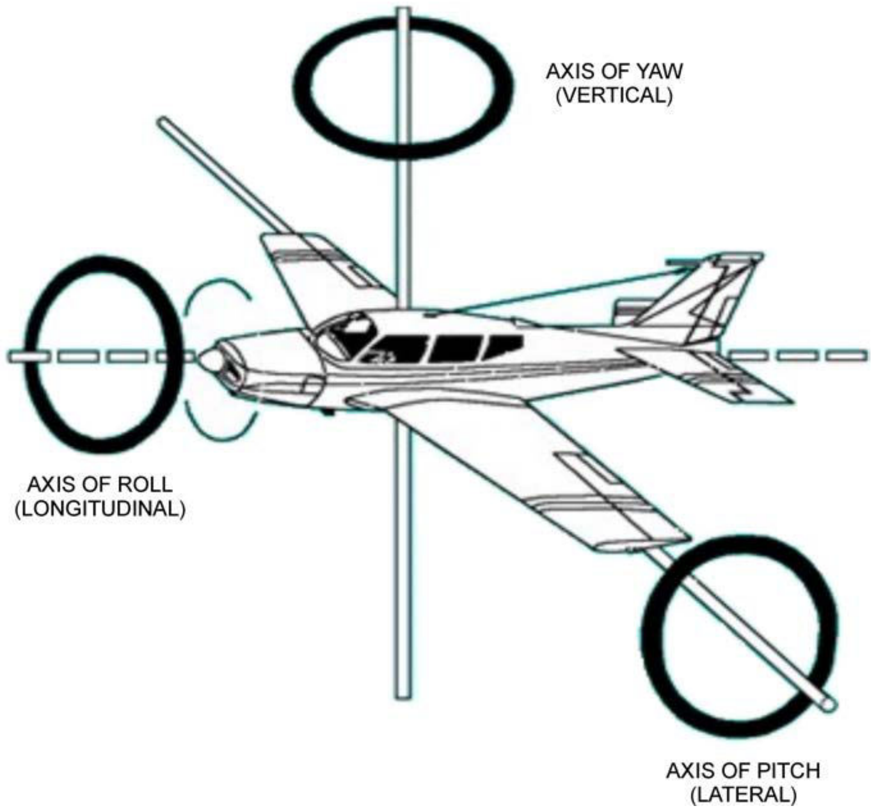
CONTROL SURFACES



"Start Flying", Controlling the Aircraft, (2007). Retrieved October 24, 2007, from http://www.startflying.com/new%20site/controlling_aircraft.htm

Figure 12B-1 Axes of Rotation

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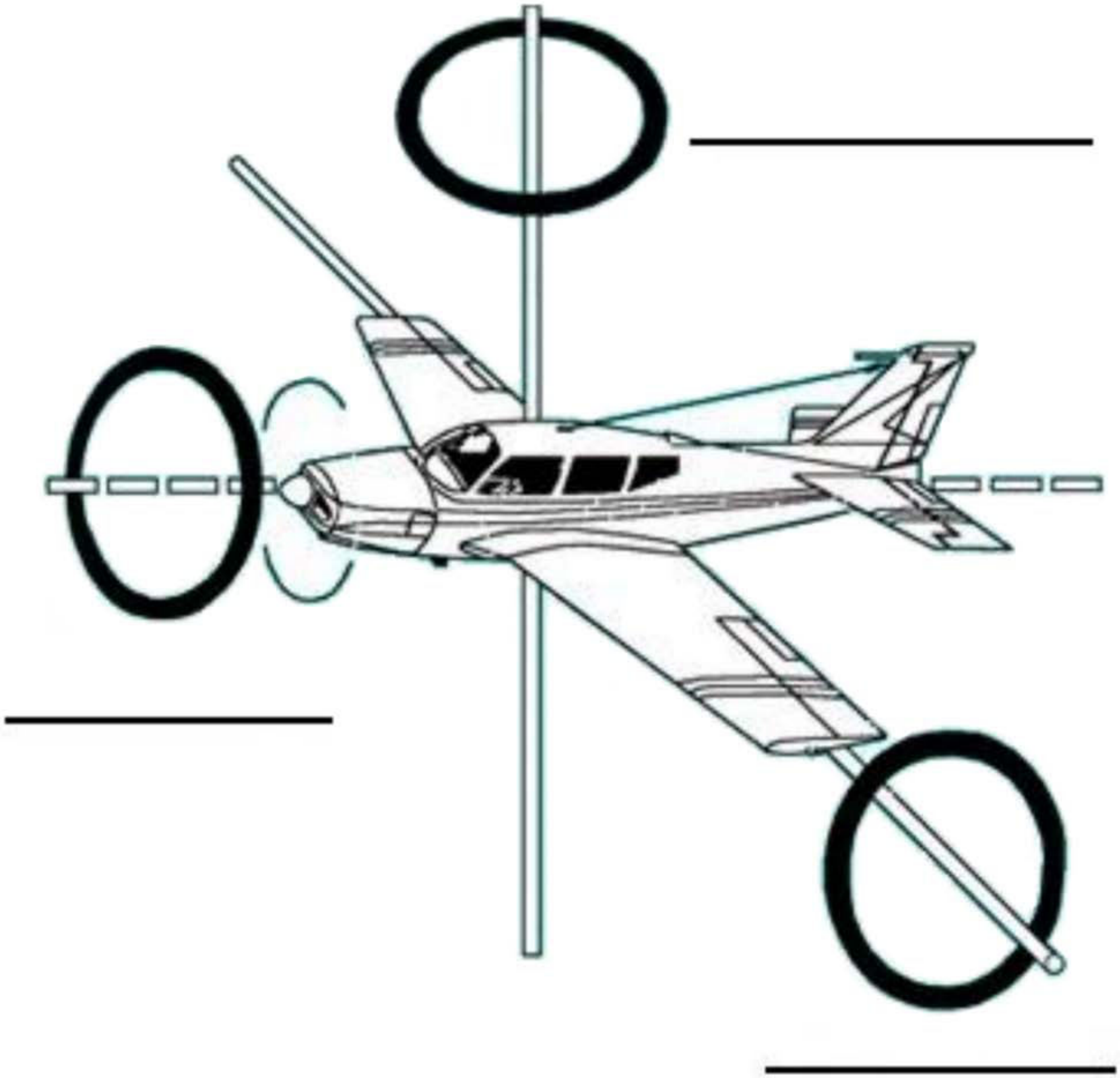
AXES OF ROTATION



"Controlling the Aircraft", Start Flying, (2007). Retrieved October 24, 2007, from http://www.startflying.com/new%20site/controlling_aircraft.htm

Figure 12C-1 Axes of Rotation

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ASI WORKSHEET

______ KNOTS

______ KNOTS

______ KNOTS

______ KNOTS

______ KNOTS

______ KNOTS

Director Cadets 3, 2008, Ottawa, ON: Department of National Defence

Figure 12D-1 ASI Worksheet

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ASI ANSWER KEY

30 KNOTS

50 KNOTS

170 KNOTS

98 KNOTS

120 KNOTS

65 KNOTS

Director Cadets 3, 2008, Ottawa, ON: Department of National Defence

Figure 12E-1 ASI Answer Key

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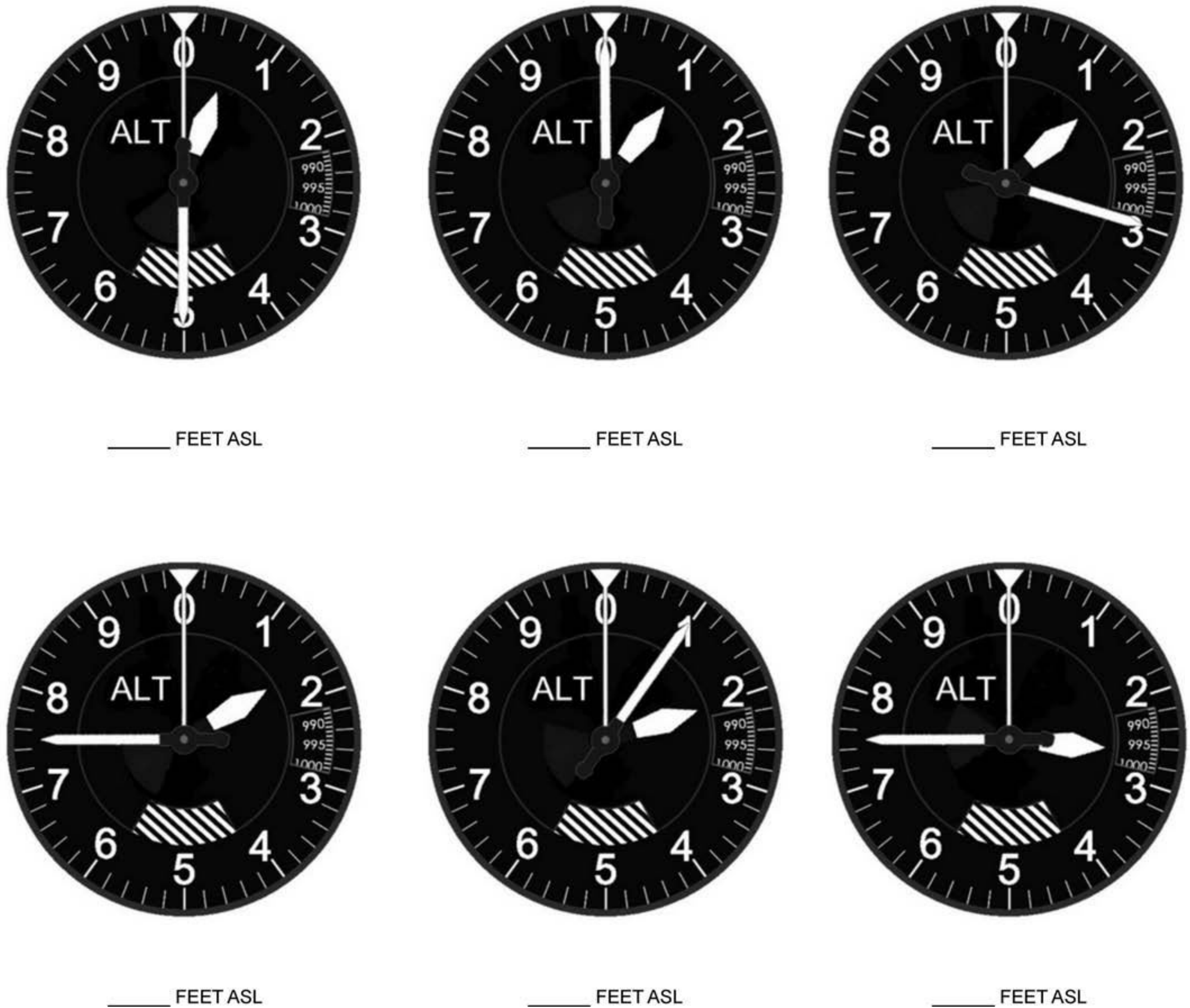
ALTIMETER WORKSHEET



Director Cadets 3, 2008, Ottawa, ON: Department of National Defence

Figure 12F-1 Altimeter Worksheet

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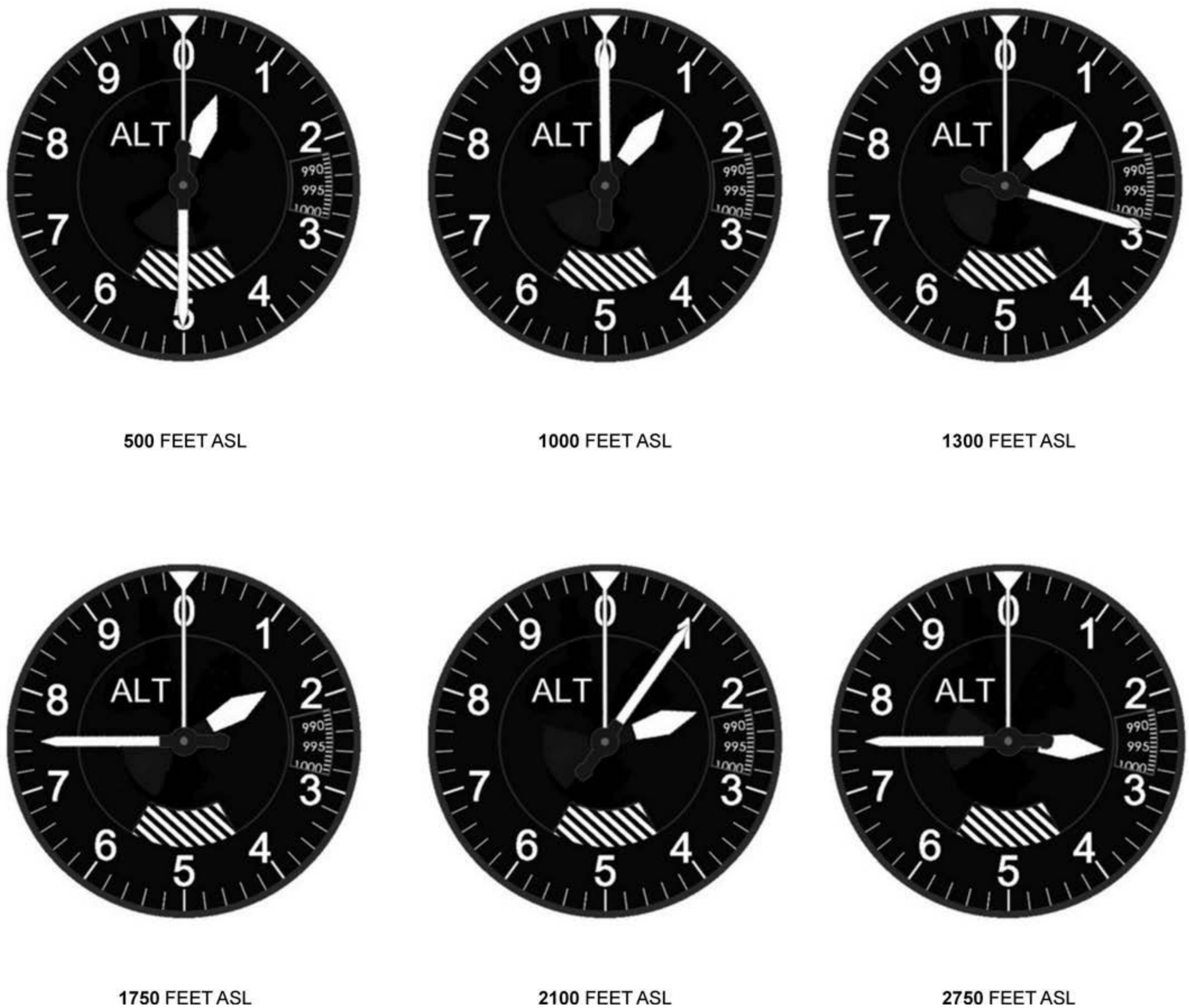
ALTIMETER ANSWER KEY



Director Cadets 3, 2007, Ottawa, ON: Department of National Defence

Figure 12G-1 Altimeter Answer Key

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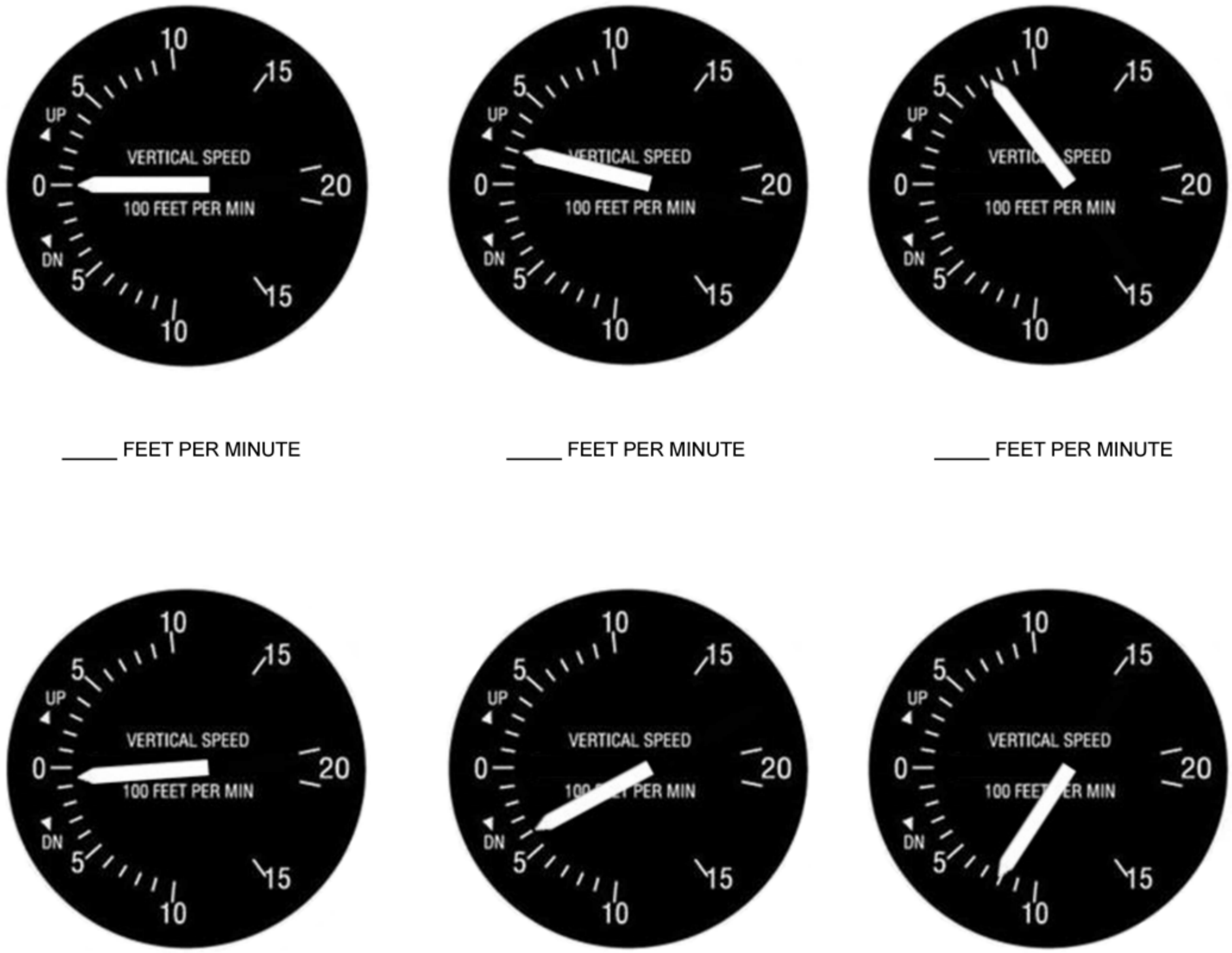
VSI WORKSHEET



_____ FEET PER MINUTE

_____ FEET PER MINUTE

_____ FEET PER MINUTE

_____ FEET PER MINUTE

_____ FEET PER MINUTE

_____ FEET PER MINUTE

Director Cadets 3, 2007, Ottawa, ON: Department of National Defence

Figure 12H-1 VSI Worksheet

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VSI ANSWER KEY

0 FEET PER MINUTE

+200 FEET PER MINUTE

+700 FEET PER MINUTE

-50 FEET PER MINUTE

-400 FEET PER MINUTE

-800 FEET PER MINUTE

Director Cadets 3, 2007, Ottawa, ON: Department of National Defence

Figure 12I-1 VSI Answer Sheet

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INSTRUCTIONS FOR CREATION OF PITOT STATIC INSTRUCTIONAL AIDS

RESOURCES

- One sheet of Bristol board per training aid,
- One brass Acco fastener per training aid,
- Pencil,
- Compass from a geometry set,
- Ruler or straight edge,
- Coloured markers, and
- Poster board for making dial hands.

INSTRUCTIONS – ASI

1. Draw a representation of an ASI centred on the Bristol board. This will include all of the numbers and coloured arcs/lines. Use figures located at Annex D as guides for layout.
2. Colour in the arcs and lines with the appropriate colours for the green arc, yellow arc and red line. Colouring in the white arc is optional as it is not covered in PO S331.
3. Cut out a dial hand from the poster board.
4. Attach the dial hand to the centre of the representation using the brass Acco fastener.
5. Ensure that the hand can move when needed, but there is enough friction to keep them from moving on their own.

INSTRUCTIONS – ALTIMETER

1. Draw a representation of an altimeter's face centred on the Bristol board. This will include all of the numbers and graduated lines in between the numbers. Use figures located at Annex F as guides for layout.
2. Cut dial hands from the poster board to represent the hands of an altimeter.
3. Colour in the altimeter. To add variety of colour, use yellow and black for the polygon shape under the hands pivot point.
4. Attach the hands to the centre of the altimeter representation using the brass Acco fastener.
5. Ensure that the hands can move when needed, but there is enough friction to keep them from moving on their own.

INSTRUCTIONS – VSI

1. Draw a representation of a VSI centred on the Bristol board. This will include all of the numbers on the positive and negative scales. Ensure that zero is located on the left side. Use the figures located in Annex G as guides for layout.
2. Colour in the VSI.
3. Cut out a dial hand from poster board and attach it to the centre of the representation using the brass Acco fastener.
4. Ensure that the hand can move when needed, but there is enough friction to keep it from moving on its own.

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TRIVIAL PURSUIT QUESTIONS

These are suggested questions that can be used for the Trivial Pursuit game in TP 5. The instructor is able to modify this list in any way. When asking a question, first set the specific training aid to the desired reading. Then allow the team whose turn it is to provide an answer. Be sure to rotate instruments every question.

ASI QUESTIONS

For each question, set the ASI training aid to the desired value. These can be asked in any order desired.

1. 125 KIAS
2. 65 KIAS
3. 40 KIAS
4. 50 KIAS
5. 75 KIAS
6. 180 KIAS
7. 210 KIAS
8. 98 KIAS
9. 110 KIAS
10. 55 KIAS

ALTIMETER QUESTIONS

For each question, set the altimeter training aid to the desired value. These can be asked in any order desired.

1. 8 900 feet ASL
2. 1 300 feet ASL
3. 2 600 feet ASL
4. 11 000 feet ASL
5. 7 500 feet ASL
6. 1 250 feet ASL
7. 600 feet ASL
8. 400 feet ASL
9. 300 feet ASL
10. 1 000 feet ASL

VSI QUESTIONS

For each question, set the VSI training aid to the desired value. These can be asked in any order desired.

1. +200 feet per minute
2. +300 feet per minute
3. +150 feet per minute

4. +500 feet per minute
5. +800 feet per minute
6. -1 000 feet per minute
7. -250 feet per minute
8. -400 feet per minute
9. -900 feet per minute
10. -1 200 feet per minute

LOCATION OF ANTI-TORQUE ROTOR

Airforce Imagery, 2008, CH-149 Cyclone. Copyright 2006 by Sikorsky Aircraft Corporation. Retrieved April 9, 2008, from http://www.airforceimagery.forces.gc.ca/netpub/server.np?find&catalog=casimages&template=detail2_e.np&field=itemid&op=matches&value=3018&site=casimages

Figure 12L-1 Location of Anti-Torque Rotor

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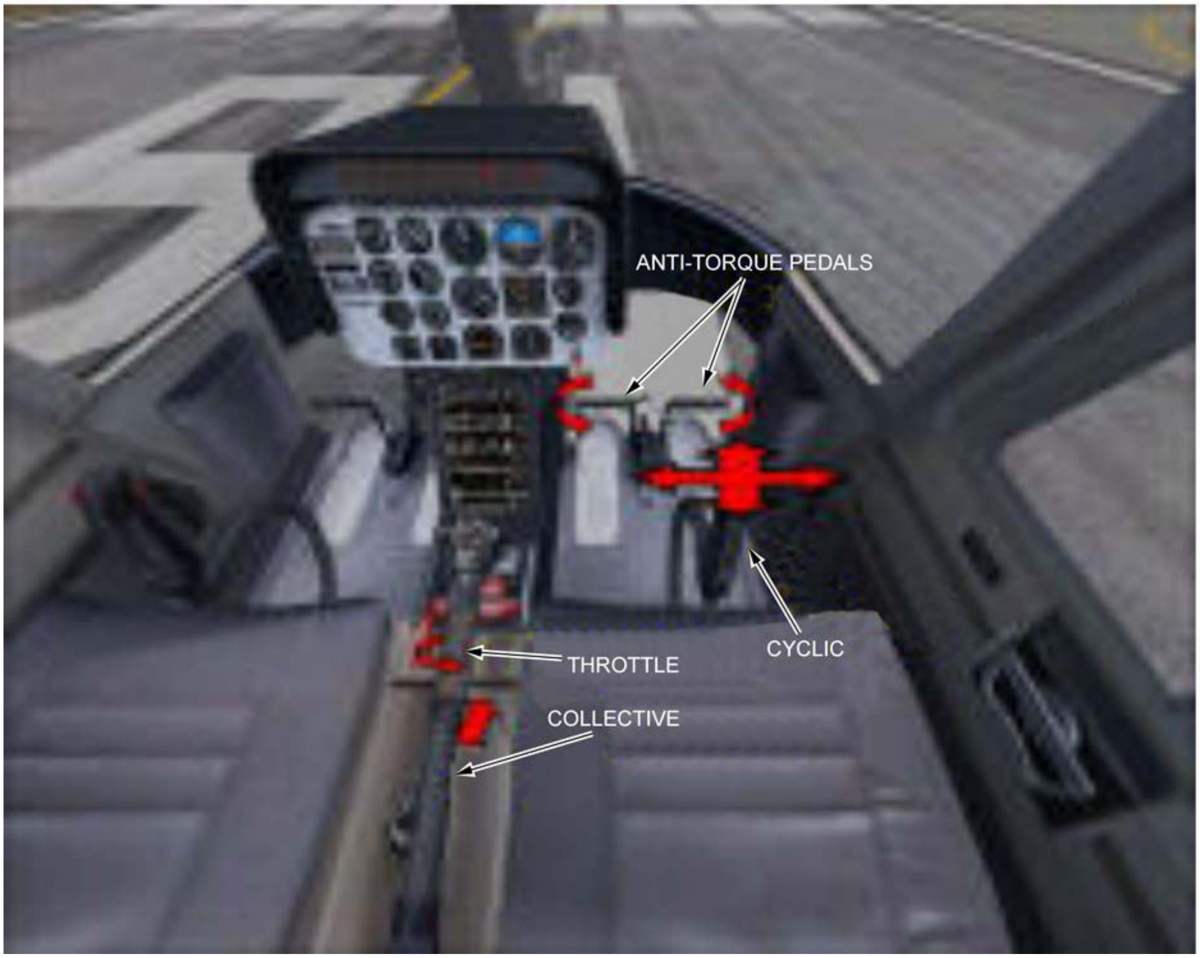
HELICOPTER CONTROL INPUTS



AVSIM Online, by S. Cartwright, 2004, Helicopter Tutorial, Copyright 2004 by AVSIM Online. Retrieved April 8, 2008, from http://www.avsim.com/pages/0604/heli/helitutorial.htm

Figure 12M-1 Helicopter Control Inputs

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CHAPTER 13

PO 336 – IDENTIFY METEOROLOGICAL CONDITIONS

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 1

EO M336.01 – DESCRIBE PROPERTIES OF THE ATMOSPHERE

Total Time: 30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create a slide of the divisions of the atmosphere located at Annex A.

Bring resources needed for demonstration in TP 2.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to introduce the cadet to the properties of the atmosphere.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have described properties of the atmosphere.

IMPORTANCE

It is important for cadets to describe properties of the atmosphere to enhance their understanding of how weather conditions are created.

Teaching Point 1 — **Describe the Composition of the Atmosphere**

Time: 5 min — Method: Interactive Lecture

COMPOSITION OF THE ATMOSPHERE

The atmosphere is composed of a mixture of invisible gases. These gases make up the majority of the atmosphere. There are also small particles of dust and debris in the lower levels of the atmosphere.

The Breakdown of the Major Gases

At altitudes of up to 250 000 feet above sea level (ASL), the atmosphere is composed primarily of nitrogen, oxygen, argon, carbon dioxide, hydrogen, water vapour, and several other gases. Each of these gases comprises a certain percentage of the atmosphere.

- **Nitrogen.** Nitrogen is the most abundant gas by percentage of the atmosphere at 78 percent.
- **Oxygen.** Oxygen is the second most abundant gas by percentage of the atmosphere at 21 percent.
- **Other.** The rest of the gases make up approximately 1 percent of the atmosphere.

The Importance of Water Vapour

Water vapour is found only in the lower layers of the atmosphere. The amount of water in the atmosphere is never constant, but it is the most important of the gases from the standpoint of weather. It can change from a gas into water droplets or ice crystals and is responsible for the formation of clouds.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. How much of the atmosphere is composed of nitrogen?

Q2. How much of the atmosphere is composed of oxygen?

Q3. From the standpoint of weather, which gas is the most important?

ANTICIPATED ANSWERS

A1. 78 percent.

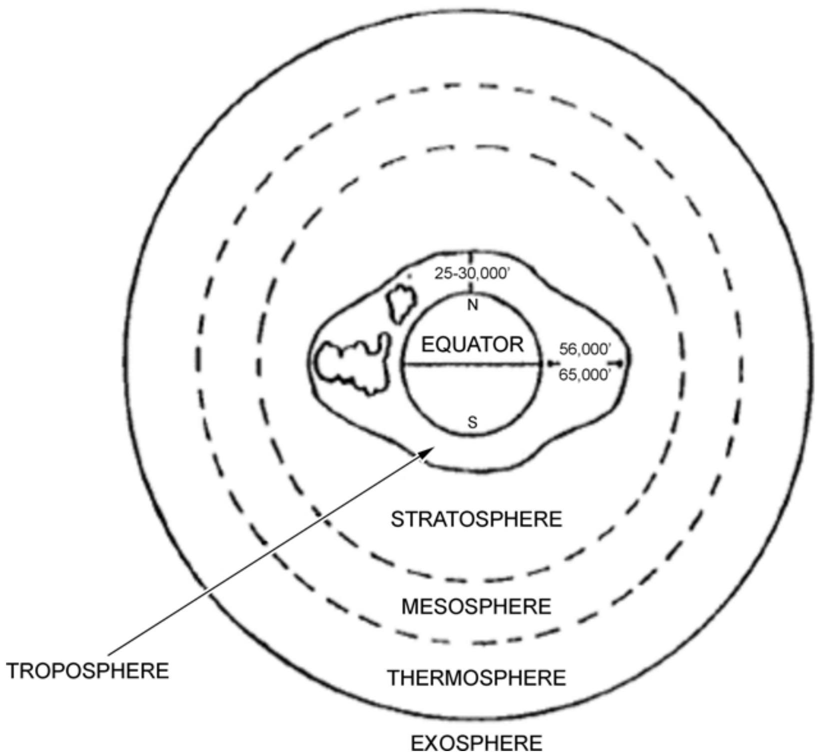
A2. 21 percent.

A3. Water vapour.

Teaching Point 2 **Illustrate the Divisions of the Atmosphere**

Time: 10 min Method: Interactive Lecture

DIVISIONS OF THE ATMOSPHERE



A. F. MacDonald and I. L. Peppler, From the Ground Up, Aviation Publishers Co. Limited (p. 123)

Figure 13-1-1 The Four Layers of the Atmosphere

The atmosphere is divided into four distinct layers which surround the earth for many hundreds of miles. These layers are the:

- troposphere,
- stratosphere,
- mesospehere, and
- thermosphere.

The exosphere is not actually a layer of the atmosphere; it is actually the first vestiges of outer space.

Show the slide located at Annex A.

Illustrate each layer of the atmosphere using the tennis ball or small globe and the clear plastic bowls. Place the tennis ball on a table, and as you introduce a new layer of the atmosphere, place a plastic bowl over the tennis ball.

The Troposphere

The troposphere is the lowest layer of the atmosphere. The troposphere starts at ground level and extends to varying heights ASL (see Figure 13-1-1). Within the troposphere air pressure, density and temperature decrease with altitude. Temperature will drop to a low of -56 degrees Celsius. Most weather occurs in this layer of the atmosphere due to the presence of water vapour as well as strong vertical currents caused by terrestrial radiation. Terrestrial radiation causes the troposphere to extend to varying altitudes. There is more radiation at the equator than at the poles.

The phenomenon known as the jet stream exists in the upper parts of the troposphere.

The top of the troposphere is known as the tropopause, which acts as a boundary between the troposphere and the stratosphere.

The Stratosphere

The stratosphere extends 50 000 feet upwards from the tropopause. The pressure continues to decrease in the stratosphere. The temperature will gradually rise to 0 degrees Celsius. It is in the stratosphere that the bulk of the ozone layer exists. This prevents the more harmful solar radiation from reaching the earth's surface, which explains the rise in temperature.

The top of the stratosphere is called the stratopause, which acts as a boundary between the stratosphere and the mesosphere.

The Mesosphere

The mesosphere is characterized by a decrease in temperature. The temperature will reach a low of -100 degrees Celsius at 275 000 feet ASL. It is in the mesosphere that meteorites will usually burn up.

The top of the mesosphere is known as the mesopause, which acts as a boundary between the mesosphere and the thermosphere.

The Thermosphere

The highest of the four layers, the thermosphere is so named due to its intense temperatures. This is the first layer to be affected by solar radiation and what few oxygen molecules there are in this layer will absorb a high amount of that radiation. The actual temperature will vary depending on solar activity, but it can exceed 15 000 degrees Celsius.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. Name the four layers of the atmosphere.

Q2. In which layer does most weather occur?

Q3. In which layer is the ozone layer found?

ANTICIPATED ANSWERS

A1. Troposphere, stratosphere, mesosphere, and thermosphere.

A2. The troposphere.

A3. The stratosphere.

Teaching Point 3 | **Explain International Civil Aviation Organization (ICAO) Standard Atmosphere**

Time: 5 min | Method: Interactive Lecture

ICAO STANDARD ATMOSPHERE

The decrease in temperature, pressure and density with altitude is not constant, but varies with local conditions. For the purposes of aviation, it is required that an international standard be set. Different regions have different standards.

The Basis of ICAO Standards in North America

The ICAO standard for North America is based on the summer and winter averages for 40 degrees north latitude. These averages include air pressure, air density and air temperature.

The Assumptions for Standard Atmosphere in North America

ICAO standards for North America assume the following conditions:

- the air is a perfectly dry gas;
- a mean sea level pressure of 29.92 inches of mercury;
- a mean sea level temperature of 15 degrees Celsius; and
- temperature decreases with altitude at a rate of 1.98 degrees Celsius per 1 000 feet.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. Why is there an international standard atmosphere?

Q2. What is the basis for ICAO standard atmosphere in North America?

Q3. What are the four assumptions used in the ICAO standard atmosphere for North America?

ANTICIPATED ANSWERS

A1. The decrease in temperature, pressure and density with altitude is not constant, but varies with local conditions.

A2. The ICAO standard for North America is based on the summer and winter averages for 40 degrees north latitude.

A3. ICAO standards for North America assume the following conditions:

- the air is a perfectly dry gas;
- a mean sea level pressure of 29.92 inches of mercury;
- a mean sea level temperature of 15 degrees Celsius; and
- the rate at which temperature decreases with altitude is 1.98 degrees Celsius per 1 000 feet.

Teaching Point 4 | **Explain the Properties of the Atmosphere**

Time: 5 min | Method: Interactive Lecture

PROPERTIES OF THE ATMOSPHERE

The properties of the atmosphere allow for various weather conditions. There are three principle properties:

- **Mobility.** This property is the ability of the air to move from one place to another. This is especially important as it explains why an air mass that forms over the arctic may affect places in the south.
- **Capacity for Expansion.** The most important of the three properties. Air is forced to rise for various reasons. As the air pressure decreases, the air will expand and cool. This cooling may be enough for condensation to occur and clouds to form, creating precipitation.
- **Capacity for Compression.** The opposite of expansion, compression occurs when the air has cooled and becomes denser. The air will sink, decreasing in volume and increasing in temperature.

Factors Affecting the Properties of the Atmosphere

There are three factors which affect the properties of the atmosphere: temperature, density and pressure. Temperature changes air density which creates the vertical movement of the air, causing expansion and compression. The vertical movement creates pressure differences, which causes mobility across the surface as the air moves horizontally to fill gaps left by air that has moved vertically.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS

Q1. What are the three properties of the atmosphere?

Q2. Which is the most important property of the atmosphere?

Q3. What are the three factors affecting the properties of the atmosphere?

ANTICIPATED ANSWERS

A1. Mobility, capacity for expansion and capacity for compression.

A2. Capacity for expansion.

A3. Temperature, density and pressure.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. Name the four layers of the atmosphere.

Q2. Why is there an international standard atmosphere?

Q3. Which is the most important property of the atmosphere?

ANTICIPATED ANSWERS

A1. Troposphere, stratosphere, mesosphere, and thermosphere.

A2. The decrease in temperature, pressure, and density with altitude is not constant, but varies with local conditions.

A3. Capacity for expansion.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-803/PG-001, Chapter 3, Annex B, Aviation Subjects – Combined Assessment PC.

CLOSING STATEMENT

Understanding why weather occurs will allow the cadet to anticipate what could happen to the flying conditions in the near future. This will be useful for all areas of life from flight planning to deciding whether or not to take an umbrella.

INSTRUCTOR NOTES/REMARKS

N/A.

REFERENCES

C3-116 (ISBN 0-9680390-5-7) MacDonald, A. F., & Peppler, I. L. (2000). *From the Ground Up: Millennium Edition*. Ottawa, ON: Aviation Publishers Co. Limited.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 2

EO M336.02 – EXPLAIN THE FORMATION OF CLOUDS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of Annexes B to I.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to introduce the concepts of cloud formation.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have explained the formation of clouds.

IMPORTANCE

It is important for cadets to know how clouds form as it will enhance their knowledge of meteorology and their ability to predict weather.

Teaching Point 1	**Explain Cloud Classification**
Time: 5 min	Method: Interactive Lecture

CLOUD CLASSIFICATION

Clouds are classified based on type of formation and cloud height.

Types of Formation

There are two main types of cloud formations:

Show slide of Annex B.

- **Cumulus.** Cumulus clouds are formed by air that is unstable. They are cottony or puffy, and are seen mostly during warmer seasons. Cumulus clouds may develop into storm clouds.

"Victoria Weather", by UVic, School-Based Weather Station Network. Retrieved November 1, 2007, from http://www.victoriaweather.ca/clouds

Figure 13-2-1 Cumulus Cloud

- **Stratus.** Stratus clouds are formed in air that is stable. They are flat and can be seen year round, but are associated with colder temperatures.

Show slide of Annex C.

"Victoria Weather", by UVic, School-Based Weather Station Network. Retrieved November 1, 2007, from http://www.victoriaweather.ca/clouds

Figure 13-2-2 Stratus Cloud

Cloud Height

Clouds are also classified based on their height above ground level (AGL). There are four main categories:

- **Low Clouds.** The bases of low clouds range from the surface to a height of 6 500 feet AGL. Low clouds are composed of water droplets and sometimes ice crystals. Low clouds use the word stratus as either a prefix (eg, stratocumulus) or a suffix (eg, nimbostratus).
- **Middle Clouds.** The bases of middle clouds range from 6 500 to 23 000 feet AGL. They are composed of ice crystals or water droplets, which may be at temperatures above 0 degrees Celsius. Middle clouds use the prefix of "alto" (eg, altocumulus).
- **High Clouds.** The bases of high clouds range from 16 500 to 45 000 feet, with an average of 25 000 feet in the temperate regions of the earth. High clouds are composed of ice crystals. High clouds use the prefix of "cirrus" or "cirro" (eg, cirrocumulus).
- **Clouds of Vertical Development.** The base of these clouds may be as low as 1 500 feet AGL and may rise as high as the lower reaches of the stratosphere. They may appear as isolated clouds or may be seen embedded in layers of clouds. Clouds of vertical development are associated with thunderstorms and other phenomena which occur during the summer months.

Show slide of Annex D.

The following chart includes a brief description of the more common cloud types.

Cloud Name	Cloud Family	Cloud Description
Cirrus	High	High, thin, wispy clouds blown by high winds into long streamers. Cirrus clouds usually move across the sky from west to east. They generally indicate pleasant weather.
Cirrocumulus	High	Appear as small, round white puffs. The small ripples in the cirrocumulus sometimes resemble the scales of a fish. A sky with cirrocumulus clouds is sometimes referred to as a “mackerel sky.”
Altocumulus	Middle	Appear as grey, puffy masses, sometimes in parallel waves or bands. The appearance of these clouds on a warm, humid summer morning often means thunderstorms will occur by late afternoon.
Altostratus	Middle	A grey or blue-grey layer cloud that typically covers the entire sky. In the thinner areas of the cloud, the sun may be dimly visible as a round disk. This cloud appears lighter than stratus clouds.
Stratus	Low	Uniform grey layer cloud that often covers the entire sky. They resemble fog that does not reach the ground. Usually no precipitation falls from stratus clouds, but sometimes they may drizzle.
Nimbostratus	Low	Dark grey layer clouds associated with continuously falling rain or snow. They often produce precipitation that is usually light to moderate.
Stratocumulus	Low	A series of rounded masses that form a layer cloud. This type of cloud is usually thin enough for the sky to be seen through breaks.
Cumulus	Vertical Development	Puffy clouds, which are thick, round, and lumpy. They sometimes look like pieces of floating cotton. They usually have flat bases and round tops.
Cumulonimbus	Vertical Development	Thunderstorm clouds that form if cumulus clouds continue to build. Violent vertical air currents, hail, lightning, and thunder are associated with the cumulonimbus clouds.

Director Cadets 3, 2007, Ottawa, ON: Department of National Defence

Figure 13-2-3 Common Clouds

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. How are clouds classified?

Q2. What are the two types of cloud formations?

Q3. What are the four categories of cloud height?

ANTICIPATED ANSWERS

A1. By type of formation and height.

A2. Cumulus and stratus.

A3. Low clouds, middle clouds, high clouds and clouds of vertical development.

Teaching Point 2	**Explain Air Stability**
Time: 5 min	Method: Interactive Lecture

AIR STABILITY

At the surface, the normal flow of air is horizontal. Disturbances may occur, which will cause vertical currents of air to develop. This is normally caused by a change in temperature. If the air that is displaced resists the change, then it is said to be stable. If it does not resist the change then it is unstable. When air rises, it expands and cools.

Stable Air. If a mass of rising air is cooler than the air that it comes in contact with, then it will sink back to its original position. Stable air may have the following affects on flight characteristics:

- poor low-level visibility (fog may occur),
- stratus type cloud,
- steady precipitation,
- steady winds, which can change greatly with height, and
- smooth flying conditions.

Unstable Air. If a mass of rising air is still warmer than the new air around it, then the air mass will continue to rise. Unstable air may have the following affects on flight characteristics:

- good visibility (except in precipitation),
- cumulus type cloud,
- showery precipitation,
- gusty winds, and
- moderate to severe turbulence.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. What may create vertical currents?

Q2. What is stable air?

Q3. What is unstable air?

ANTICIPATED ANSWERS

A1. A change in temperature.

A2. When a mass of rising air is cooler than the air that it comes in contact with, then it will sink back to its original position.

A3. When a mass of rising air is warmer than the new air around it, then the air mass will continue to rise.

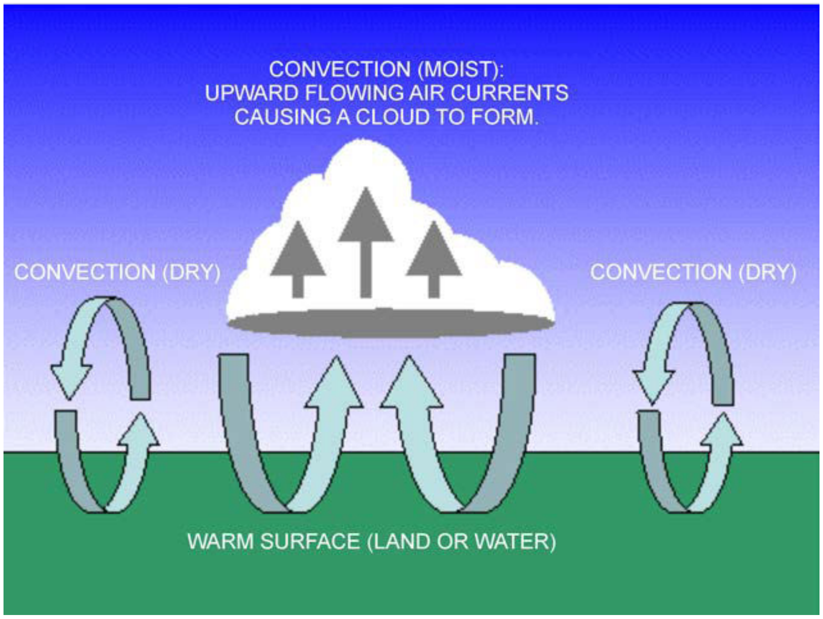
Teaching Point 3	**Explain Lifting Agents**
Time: 10 min	Method: Interactive Lecture

LIFTING AGENTS

Rising currents of air affect many weather conditions. There are five conditions that provide the lift required to initiate rising currents of air.

Show slides of Annexes E to I as applicable.

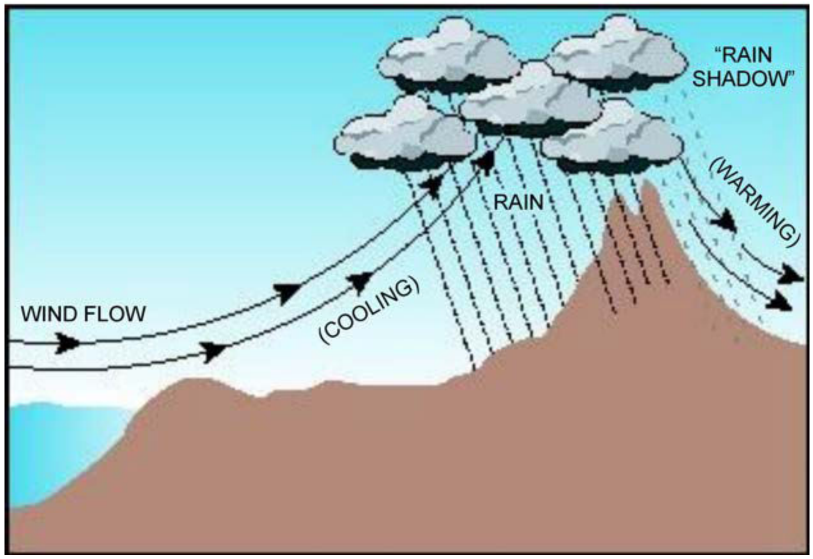
Convection. The air is heated through contact with the earth's surface. As the sun heats the surface of the earth, the air in contact with the surface warms up, rises, and expands. Convection may also occur when air moves over a warmer surface and is heated by advection.



WeatherQuestions.com, 2007, What is Convection. Copyright 2007 by WeatherStreet. Retrieved March 17, 2008, from http://www.weatherquestions.com/What_is_convection.htm

Figure 13-2-4 Convection

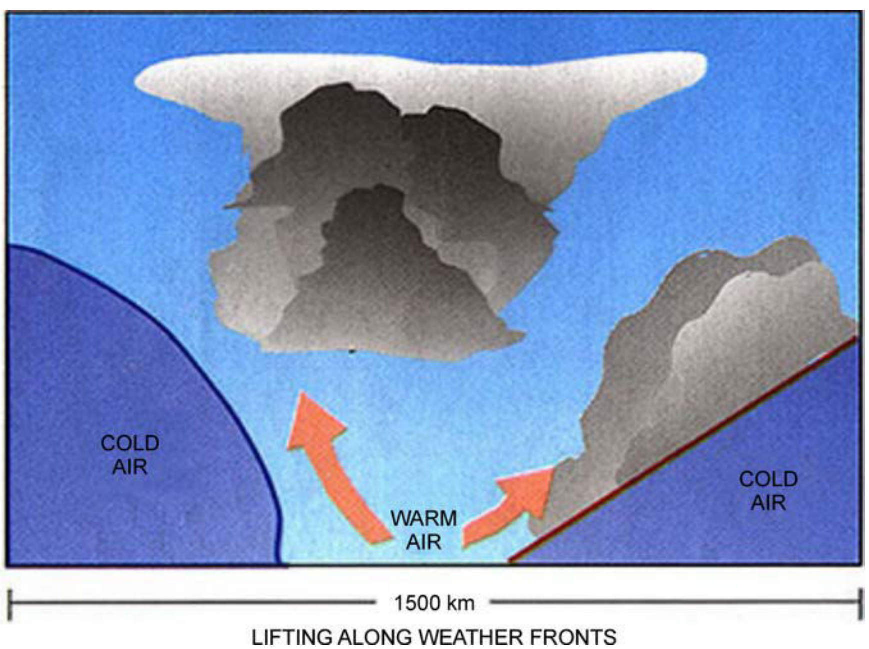
Orographic Lift. Orographic lift occurs when the sloping terrain forces the air upward. This process can be exaggerated if the air mass is already.



Water Encyclopedia, by G. H. Taylor, 2007, Water as a Climate Moderator. Copyright 2007 by Advameg. Retrieved March 17, 2008, from http://www.waterencyclopedia.com/Ce-Cr/Climate-Moderator-Water-as-a.html

Figure 13-2-5 Orographic Lift

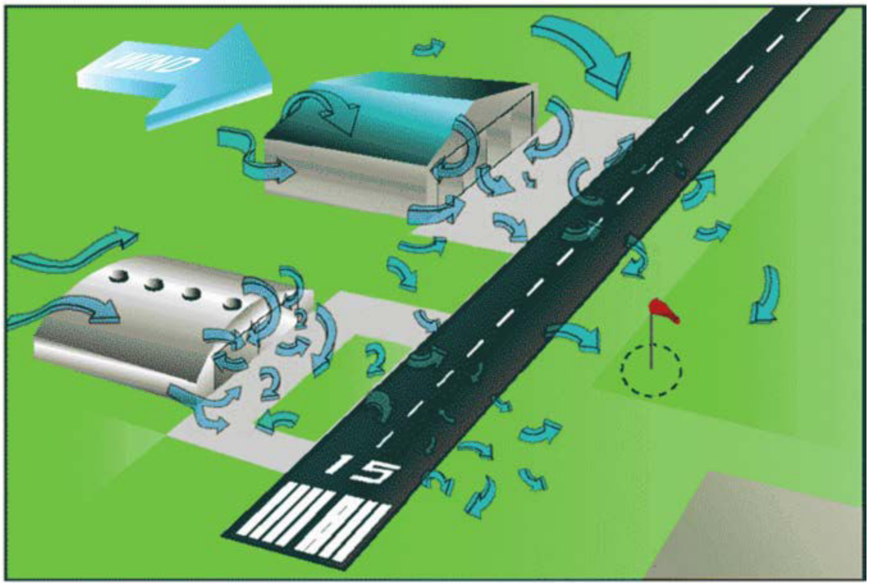
Frontal Lift. When different air masses meet, the warmer air is forced upwards by the denser cold air. This process may be exaggerated if the warm air mass becomes unstable.



Federation of American Scientists, by N. M. Short, Sr, 2007, Atmospheric Circulation: Weather Systems. Copyright 2007by FAS. Retrieved March 17, 2008, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

Figure 13-2-6 Frontal Lift

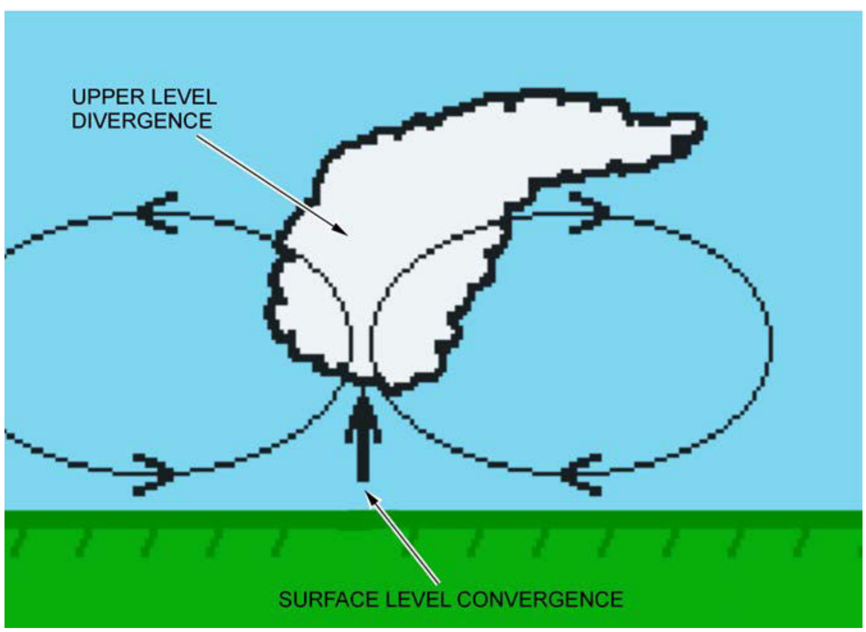
Mechanical Turbulence. Air moving over the ground may be affected by terrain that is not as pronounced as mountains. Forests, buildings, large ditches and quarries also affect the air through friction. This friction causes eddies, which are usually confined to the first few thousand feet of the troposphere. This process may be exaggerated if the air mass becomes or is already unstable.



Free Online Private Pilot Ground School, 2006, Aviation Weather–Principles. Copyright 2006. Retrieved March 17, 2008, from http://www.free-online-private-pilot-ground-school.com/Aviation-Weather-Principles.html

Figure 13-2-7 Mechanical Turbulence: Man-Made

Convergence. In a low pressure system, the wind blows toward the centre of the system. The excess air that collects here is forced upward to higher altitudes.



The Weather Doctor, by K. C. Heidron, PhD, 2002, What Goes Up: Part 3 Convergence and Divergence. Retrieved March 17, 2008, from http://www.islandnet.com/~see/weather/elements/whatgoesup3.htm

Figure 13-2-8 Convergence

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. Explain how convection (as a source of lift) occurs.

Q2. Explain orographic lift.

Q3. Explain frontal lift.

ANTICIPATED ANSWERS

A1. Convection is caused by heating of the air that is in contact with the surface of the earth.

A2. Orographic lift occurs when the sloping terrain forces the air upward.

A3. When different air masses meet, the warmer air is forced upward by the denser cold air. This process may be exaggerated if the warm air mass becomes unstable.

Teaching Point 4	**Describe Cloud Formation**
Time: 5 min	Method: Interactive Lecture

CLOUD FORMATION

Clouds are formed by the lifting agents and air stability.

Clouds are formed in two ways. Either the temperature drops to the saturation point of the air or the temperature is constant but the amount of water in the air increases.

Relating Lifting Agents to Air Stability

Each of the lifting agents described have an effect on, or is affected by, air stability. Convection, for example, is normally associated with unstable air since heat causes the convection, and is also a source of instability in the air.

Another example would be orographic lift, which is usually associated with stable air. After the air has been forced up by the terrain, it cools and becomes dense. The effect is similar to positive stability in an airplane.

Relating Air Stability to Types of Formation

Air stability will have a direct affect on cloud formation. Clouds created in stable air will form as stratus-type clouds. Clouds formed in unstable air will form as cumulus-type clouds.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS

Q1. What are the two ways in which a cloud forms?

Q2. How does orographic lift relate to air stability?

Q3. What cloud type will form in stable air?

ANTICIPATED ANSWERS

A1. Either the temperature drops to the saturation point of the air or the temperature is constant but the amount of water in the air increases.

A2. After the air has been forced up by the terrain, it cools and becomes dense. The effect is similar to positive stability in an airplane.

A3. Clouds created in stable air will form as stratus-type clouds.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. What are the two types of cloud formation?

Q2. Define unstable air.

Q3. What cloud type will form in unstable air?

ANTICIPATED ANSWERS

A1. Cumulus and stratus.

A2. When a mass of rising air is warmer than the new air around it, then the air mass will continue to rise.

A3. Clouds created in unstable air will form as cumulus-type clouds.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-803/PG-001, Chapter 3, Annex B, Aviation Subjects – Combined Assessment PC.

CLOSING STATEMENT

Knowing how a cloud is formed will help predict the weather conditions that may exist. Conversely, knowing the weather conditions will assist in determining what clouds will form later in the day, and it may be possible to predict what the weather for the day will be.

INSTRUCTOR NOTES/REMARKS

N/A.

REFERENCES

A3-044 CFACM 2-700 Air Command. (2001). *Air Command Weather Manual*. Ottawa, ON: Department of National Defence.

C3-116 (ISBN 0-9680390-5-7) MacDonald, A. F., & Peppler, I. L. (2000). *From the Ground Up: Millennium Edition*. Ottawa, ON: Aviation Publishers Co. Limited.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 3

EO M336.03 – EXPLAIN THE EFFECTS OF AIR PRESSURE ON WEATHER

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of Annexes J to O.

Photocopy handouts of Annex P for each cadet.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to introduce the cadets to the effects of air pressure.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have explained the effects of air pressure on weather.

IMPORTANCE

It is important for cadets to explain the effects of air pressure on weather in order to appreciate patterns of weather and the movement of air.

Teaching Point 1 | **Explain the Polar Front Theory**

Time: 10 min | Method: Interactive Lecture

Certain terms used in this document are meant to be relative; they may not necessarily have a fixed value. For example, low pressure system does not necessarily mean that the pressure of the air is lower than mean sea level. It means that the air pressure in that system is lower than the air pressure around the system.

POLAR FRONT THEORY

The Polar Front theory was conceived by Norwegian meteorologists, who claimed that the interaction between the consistently high pressure area over the Arctic (and Antarctic) and the relatively lower pressure areas over the lower latitudes may provide force to the movement of air.

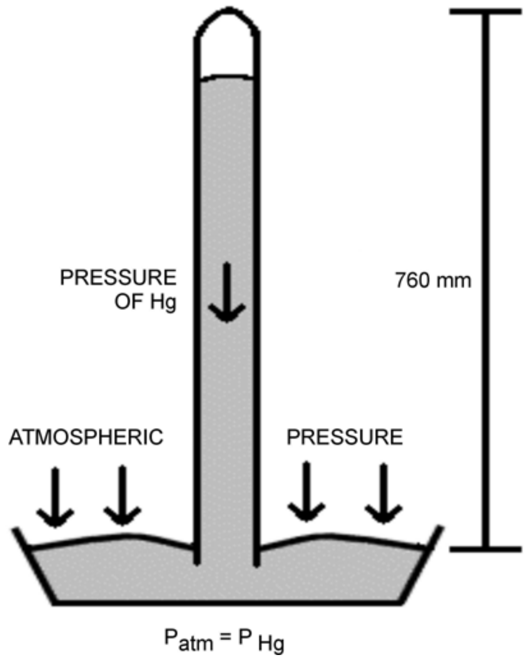
Definition of Atmospheric Pressure

Show slide of Annex J.

Atmospheric Pressure. The pressure of the atmosphere at any point due to the weight of the overlying air. Pressure at the surface of the earth is normally measured using a mercury barometer and is expressed in mm of mercury (mm Hg) or inches of mercury ("Hg). The barometer is essentially an upside-down graduated, test tube that is partially immersed in a bowl of mercury. As the pressure of the air over the bowl increases, the mercury is forced further up the test tube, providing a higher reading.

Pressure is a force and, in meteorological work, it is common to use hectopascals (hPa) to measure pressure. One hectopascal is 1 000 dynes (a unit of force) of force exerted on a 1 cm^2 area.

The average pressure of the atmosphere at sea level is normally expressed as 760 mm Hg (29.92 "Hg), which is the same as 1013.2 hPa. Public radio and television weather broadcasts (such as the Weather Network or Environment Canada) will express pressure in kilopascals (kPa). One kPa is equal to 10 hPa, so that 1013.2 hPa would be equal 101.32 kPa.



Chemistry Tutorial Notes, Department of Chemistry, Texas A&M University, 2006, Properties of Gases, Copyright 2006 by Texas A&M University. Retrieved April 4, 2008 from http://www.chem.tamu.edu/class/majors/tutorialnotefiles/pressure.htm

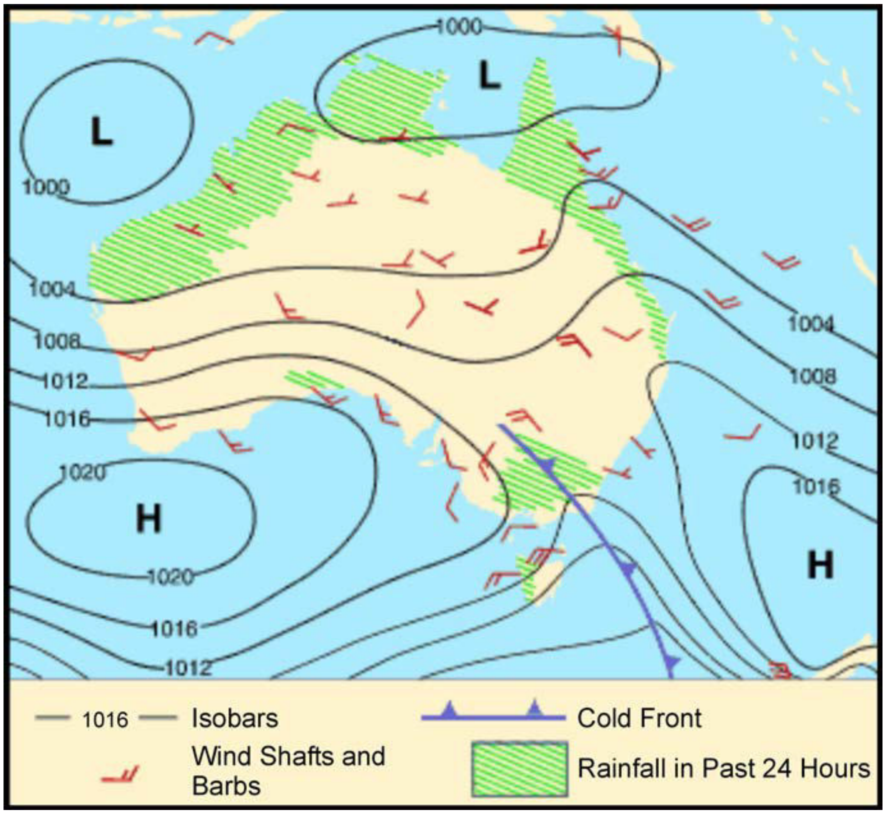
Figure 13-3-1 Barometer

Pressure Systems

There are pressure reading stations all over North America. Each station will send its readings to a main forecasting office, which will plot the information on a weather map.

Show slide of Annex K.

- **Isobars.** Areas of like pressure are joined by lines called isobars (from Greek *isos* [same] and *baros* [weight]). On a weather map, isobars will look similar to contour lines found on a topographical map. The isobars form roughly concentric circles, each circle being four hPa different than the circles before and after it. Groups of isobars will indicate areas of relatively high pressure, or relatively low pressure.



Australian Government, Bureau of Meteorlogy, 2008, Air Masses and Weather Maps, Copyright 2008 by Commonwealth of Australia, Bureau of Meteorology. Retrieved April 7, 2008 from http://www.bom.gov.au/info/ftweather/page_7.shtml

Figure 13-3-2 Isobars on a Weather Map

- **Low Pressure Areas.** Low pressure areas (often called lows, cyclones, or depressions) are areas of relatively lower pressure, with the lowest pressure in the centre. Lows will normally move in an easterly direction at an average rate of 800 km per day during the summer and 1 100 km per day in the winter. Lows are associated with thunderstorms and tornadoes, and do not stay in one place for very long. In the northern hemisphere, air moves around a low pressure in a counter-clockwise direction.
- **High Pressure Areas.** High pressure areas (often called anti-cyclones) are areas of relatively higher pressure, with the highest pressure in the centre. Winds are usually light and variable. High pressure areas move very slowly, sometimes staying stationary for days at a time. In the northern hemisphere, air moves around a high in a clockwise direction.

An Air Mass Over the Polar Regions

Polar air is typically cold and dry.

An Air Mass Over the Equatorial Regions

The air over the equator is tropical, therefore warm and moist.

Movement at the Polar Front

The transition zone between the polar air and the equatorial air is known as the polar front. Due to the differences in the properties of the two air masses, many depressions (low pressure areas) form along the polar front. The cold air moves from north-east to south-west in the northern hemisphere, while the warm air moves in the opposite direction. The result is constant instability as the cold air bulges south and the warm air bulges north. The cold air moves faster than the warm air and eventually envelopes it.

The movement of the air at the polar front is thought to be a cause for the circulation of air in the troposphere.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. What is a hectopascal?

Q2. Which direction does the air move around a low pressure in the northern hemisphere?

Q3. What is the transition zone between the polar air and the tropical air known as?

ANTICIPATED ANSWERS

A1. One hectopascal is 1 000 dynes of force exerted on a 1 cm^2 area.

A2. Counter-clockwise.

A3. Polar front.

Teaching Point 2	Explain That the Properties (eg, Pressure) of an Air Mass are Taken From the Area Over Which it Forms
Time: 5 min	Method: Interactive Lecture

PROPERTIES OF AN AIR MASS

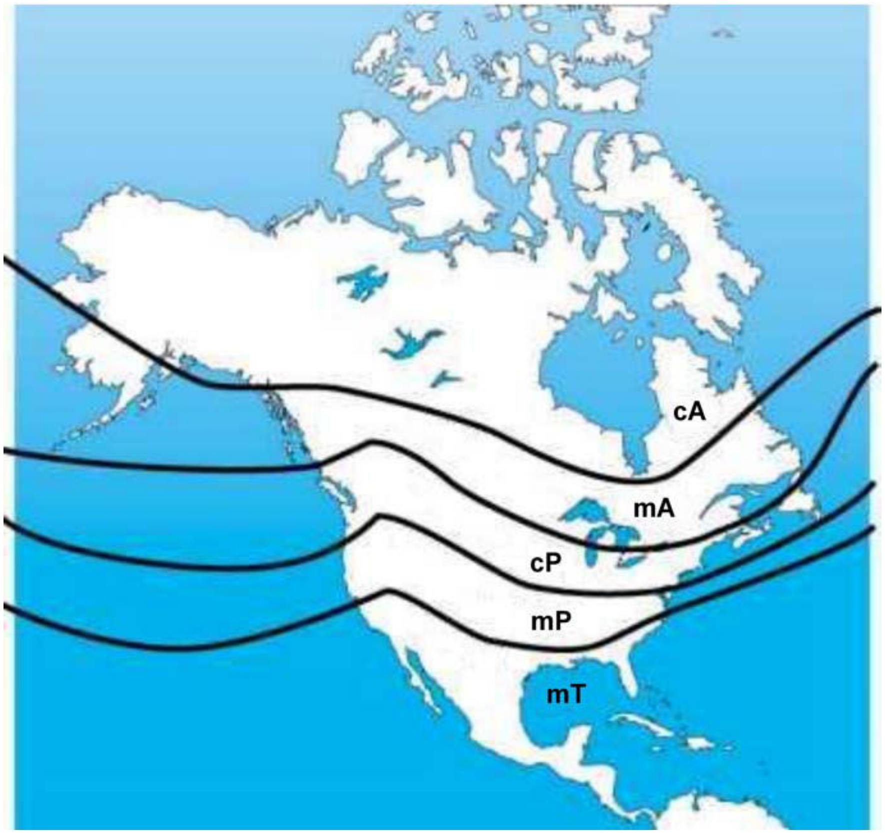
Weather forecasts used to be based solely on the existence and movement of pressure systems. Meteorologists currently base their predictions on the properties of air masses, of which pressure is only one factor.

An air mass may be defined as a large section of the troposphere with uniform properties of temperature and moisture along the horizontal plane. This means that if a horizontal cross-section was taken of an air mass, one would see layers within the air mass where the temperature and the amount of moisture would be the same throughout.

An air mass will take on the properties of the surface over which it has formed. An air mass, which has formed over the Arctic would be cold and dry, while one, which formed over the Gulf of Mexico would be warm and moist.

Air masses may be described as:

- **Continental Air Mass.** Since the air mass formed over land, this will be a dry air mass.
- **Maritime Air Mass.** Since the air mass formed over water, this will be a moist air mass.
- **Arctic Air Mass.** Since the air mass formed over the Arctic, this will be a cold air mass.
- **Polar Air Mass.** Since the air mass formed over the Polar region, this will be a cool air mass.
- **Tropical Air Mass.** Since the air mass formed over the Tropical region, this will be a warm air mass.



Meteorological Service of Canada, 2004, Frontal Systems, Copyright 2004 by Environment Canada. Retrieved April 7, 2008 from http://www.qc.ec.gc.ca/meteo/Documentation/Front_e.html

Figure 13-3-3 North American Air Masses

Show slide of Annex L.

These types of air masses are usually combined to describe the properties of temperature and moisture. For example, over Atlantic Canada one might find a maritime polar air mass, which will be cool and moist. Meanwhile prairie winters usually see continental polar or continental arctic, which will be either cool and dry or cold and dry. The five air masses in North America indicated in Figure 13-3-3 include:

- Continental Arctic (cA),
- Maritime Arctic (mA),
- Continental Polar (cP),
- Maritime Polar (mP), and
- Maritime Tropical (mT).

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. What is the definition of an air mass?

Q2. Where does an air mass obtain its properties from?

Q3. What are five air masses in North America?

ANTICIPATED ANSWERS

A1. An air mass may be defined as a large section of the troposphere with uniform properties of temperature and moisture along the horizontal plane.

A2. An air mass will take on the properties of the surface over which it has formed.

A3. Continental air mass, maritime air mass, arctic air mass, polar air mass, and tropical air mass.

Teaching Point 3	**Explain the Creation of Wind**
Time: 5 min	Method: Interactive Lecture

WIND

Wind is a major factor in flight planning and flight characteristics. Pilots must constantly be aware of the direction and speed of wind during all parts of the flight, but especially during the landing sequence.

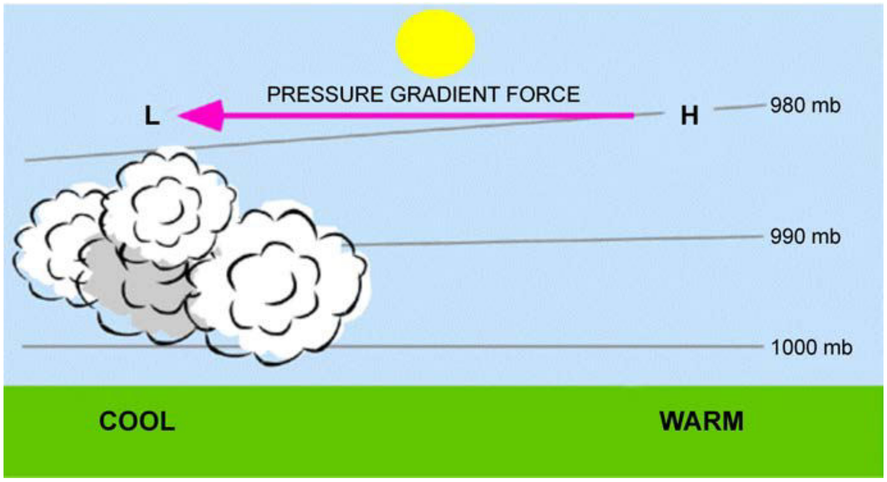
The Definition of Wind

Wind. The horizontal movement of air within the atmosphere. Wind normally moves parallel to the isobars of a pressure system. Since isobars are not straight lines, this means that the wind direction will vary at different locations along the pressure system. Wind also moves in different directions based on whether the pressure is a low or high system.

Show slide of Annex M.

Pressure Gradient

The pressure gradient is the rate of change of pressure over a given distance measured at right angles to the isobars. If the isobars are very close together, the rate of change will be steep and the wind speed will be strong. If the isobars are far apart, the rate of change will be shallow and the wind speed will be weak.



PhysicalGeography.net, Dr. M. Pidwirny, University of British Columbia Okanagan, 2007, Introduction to the Atmosphere, Copyright 2007 by M. Pidwirny. Retrieved April 7, 2008 from http://www.physicalgeography.net/fundamentals/7o.html

Figure 13-3-4 Pressure Gradient

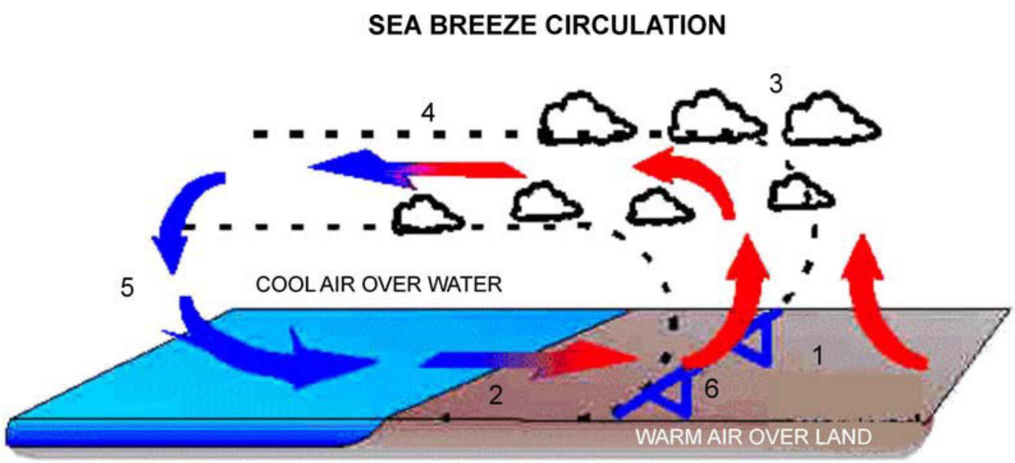
Land and Sea Breezes

Land and sea breezes are caused by the differences in temperature over land and water.

Show slides of Annexes N and O.

Note that the term breeze is used here as a technical term and has no bearing on wind strength.

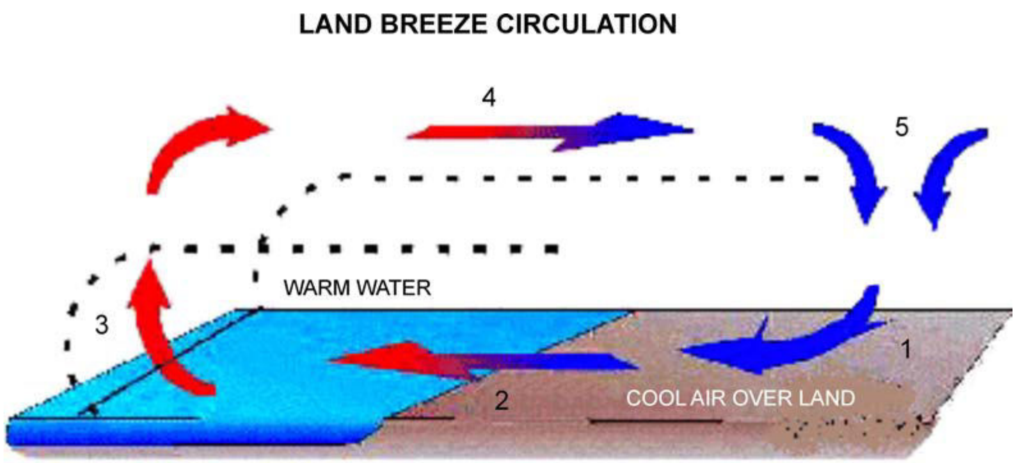
The sea breeze occurs during the day when the land heats up more rapidly than the water. This creates a lower pressure area over the land. The pressure gradient caused by this change is usually steep enough to create a wind from the water.



The Weather Doctor, K. C. Heidron, PhD, 1993, Sea and Land Breezes, Copyright 1998 by K. C. Heidron PhD. Retrieved April 7, 2008 from http://www.islandnet.com/~see/weather/elements/seabrz.htm

Figure 13-3-5 Sea Breeze

The land breeze occurs at night when the land cools down faster than the water. This creates a higher pressure over the land. The pressure gradient now moves the air from the land to the water.



The Weather Doctor, K. C. Heidron, PhD, 1993, Sea and Land Breezes, Copyright 1998 by K. C. Heidron PhD. Retrieved April 7, 2008 from http://www.islandnet.com/~see/weather/elements/seabrz.htm

Figure 13-3-6 Land Breeze

Land and sea breezes are local and affect a small area only.

Diurnal Variation

Surface winds are generally stronger during the day than at night. This is due to the heating processes, which occur during the day, creating vertical currents and pressure gradients. At night, when the heating processes cease, the vertical currents diminish and the pressure gradients become shallower.

Coriolis Force

As air moves from a high pressure system to a low pressure system, the air will not flow directly from one to the other. The rotation of the earth causes a deflection to the right (in the northern hemisphere). This force is known as Coriolis Force. Coriolis Force also explains why air moves clockwise around a high, and counter-clockwise around a low pressure system.

Veering and Backing

Veering is a change in wind direction clockwise relative to the cardinal points of a compass while backing is a change in wind direction counter-clockwise. For example, when the wind veers it will increase in direction from 090 degrees to 100 degrees; when it backs it will decrease in direction from 100 degrees to 090 degrees.

Veering and backing normally occur with changes in altitude. An increase in altitude will normally see a veer in wind direction and an increase in wind speed. A decrease in altitude will normally see a backing in wind direction and a decrease in wind speed. These changes are due to an increase in friction with the surface of the earth in the lower altitudes, and a decrease is friction in the higher altitudes.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. Define pressure gradient.

Q2. Why do sea breezes occur?

Q3. What is veering?

ANTICIPATED ANSWERS

A1. Pressure gradient is the rate of change of pressure over a given distance measured at right angles to the isobars.

A2. Sea breezes occur during the day when the land heats up more rapidly than the water, creating a lower pressure over the land.

A3. Veering is a change in wind direction clockwise relative to the cardinal points of a compass.

Teaching Point 4	Explain the Relationship Between Pressure Systems, and Wind Strength and Direction
Time: 5 min	Method: Interactive Lecture

RELATIONSHIP BETWEEN PRESSURE SYSTEMS AND WIND

Pressure and wind are interrelated, with one being the cause of the other.

Low Pressure Areas

Low pressure areas are the cause of all air movement as described by the Polar Front theory. Wind blows in a counter-clockwise direction around the low, and inwards to the centre of the system. Wind tends to be strong in a low as the pressure gradient is relatively steep causing the system to move fast over the ground. Low pressure systems are generally associated with brief periods of poor weather, as the inward flow of air acts as a vacuum.

High Pressure Areas

The wind in a high pressure areas blows in a clockwise direction around the high and outwards from the centre of the system. Wind tends to be weak in a high as the pressure gradient is normally relatively shallow causing the system to move slowly over the ground. High pressure systems are usually associated with fair weather, as the outward flow of air acts as a shield against bad weather.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS

Q1. What direction does the wind blow around a low pressure system in the northern hemisphere?

Q2. What direction does the wind blow around a high pressure system in the northern hemisphere?

ANTICIPATED ANSWERS

A1. Counter-clockwise and inwards.

A2. Clockwise and outwards.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. What is the transition zone between the polar air and the tropical air known as?

Q2. What is the definition of an air mass?

Q3. Why do sea breezes occur?

ANTICIPATED ANSWERS

A1. Polar front.

A2. An air mass may be defined as a large section of the troposphere with uniform properties of temperature and moisture along the horizontal plane.

A3. Sea breezes occur during the day when the land heats up more rapidly than the water, creating a lower pressure over the land.

Distribute handout of Annex P.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-803/PG-001, Chapter 3, Annex B, Aviation Subjects – Combined Assessment PC.

CLOSING STATEMENT

Air pressure has a significant affect on weather around the world. Low pressure systems create movement of air, which circulates the air masses around the world. The air masses are the source of the actual weather conditions that we are exposed to.

INSTRUCTOR NOTES/REMARKS

N/A.

REFERENCES

C3-116 (ISBN 0-9680390-5-7) MacDonald, A. F., & Peppler, I. L. (2000). *From the Ground Up: Millennium Edition*. Ottawa, ON: Aviation Publishers Co. Limited.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 4

EO M336.04 – EXPLAIN THE EFFECTS OF HUMIDITY AND TEMPERATURE ON WEATHER

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Gather the resources required for the in-class activity in TP 3.

Create slides of Annex Q.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for TPs 1, 2, 4, and 5 to introduce temperature, humidity and precipitation to the cadets.

An in-class activity was chosen for TP 3 as an interactive way to provoke thought about temperature and humidity.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall be expected to explain the effects of temperature and humidity on weather.

IMPORTANCE

It is important for cadets to be able to explain the effects of temperature and humidity on weather as it will allow the cadet to make more informed decisions about activities in the field, in aviation or whether to wear a raincoat.

Teaching Point 1 **Explain Humidity**

Time: 10 min Method: Interactive Lecture

HUMIDITY

Humidity is a representation of the moisture or water vapour, which is present in an air mass. While water vapour is a small percentage of the overall atmosphere, it is the only gas which can change into a solid or a liquid in ordinary atmospheric conditions. It is this characteristic which causes most weather to develop.

The moisture in an air mass originates from a body of water over which the air mass forms or passes. This body of water may be a pond or an ocean. The size of the body of water determines how much water is available for the air mass to collect, while the rate of evaporation will determine how much of that water is collected by the air mass. Water may exist in the atmosphere in two forms: invisible (gaseous) or visible (water droplets [liquid] or ice crystals [solid]).

Condensation

Condensation is a process by which a gas changes into a liquid by becoming denser. This is usually caused by a cooling process. The air is cooled to a certain temperature at which the water vapour will condense into water.

Sublimation

Sublimation is a process by which a gas changes into a solid without first becoming a liquid. This is usually caused by freezing. Sublimation occurs whenever snow, ice or hail fall from the sky. This process usually occurs in the winter, but may occur during exceptional summer storms.

Dew Point

Dew point is the temperature to which unsaturated air must be cooled, at a constant pressure, in order to become saturated. The temperature and dew point are responsible for the creation of clouds and precipitation. If the difference between the temperature and the dew point is small, then the air is considered to be nearly saturated and a small drop in temperature will see the formation of clouds or precipitation.

Relative Humidity

Relative humidity is the ratio of the actual amount of water present in the air compared to the amount of water which the same volume of air would hold if it were saturated. Temperature and pressure must remain the same, otherwise the relative humidity will change. Saturated air will have a relative humidity of 100 percent, while perfectly dry air will have a relative humidity of zero percent.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. Define condensation.

Q2. Define dew point.

Q3. Define relative humidity.

ANTICIPATED ANSWERS

A1. Condensation is a process by which a gas changes into a liquid by becoming denser.

A2. Dew point is the temperature to which unsaturated air must be cooled, at a constant pressure, in order to become saturated.

A3. Relative humidity is the ratio of the actual amount of water present in the air compared to the amount of water which the same volume of air would hold if it were saturated.

Teaching Point 2	**Explain Temperature**
Time: 15 min	Method: Interactive Lecture

TEMPERATURE

Temperature represents the amount of heat in a given object, such as the human body or air. Temperature is measured using a thermometer. In aviation weather reports, temperature is normally expressed in degrees Celsius.

The Source

The source of the energy which warms the earth and its atmosphere is the sun. Solar radiation is transmitted to the earth and its atmosphere. Some of the solar radiation is absorbed by the stratosphere, while the rest passes through to be absorbed by the earth's surface. The earth then radiates heat into the troposphere through terrestrial radiation. It is terrestrial radiation that heats the troposphere, and is why the further one gets from the surface of the earth, the lower the temperature will be in the troposphere.

The atmosphere is heated from below not from above.

Diurnal Variation

During the day, the solar radiation exceeds the terrestrial radiation and the surface of the earth becomes warmer. At night, solar radiation ceases, and the terrestrial radiation causes the surface of the earth to cool. This is called diurnal variation and causes the heating and cooling of the atmosphere.

Seasonal Variation

The axis around which the earth rotates is tilted compared to the plane of orbit around the sun. The result is that the amount of solar radiation that strikes the surface of the earth varies from season to season. In the northern hemisphere, the months of June, July, and August are warm, while the months of December, January, and February are cold.

The Heating Process

Air is a poor conductor of heat. The following are four processes which assist in getting warm air into the higher levels of the atmosphere:

- **Convection.** Air over a warm surface becomes buoyant and rises, allowing cooler air to move into the vacant location. This vertical current of air distributes the heat to the higher levels.
- **Advection.** Horizontal movement of cool air over a warm surface allows the cool air to be heated from below.
- **Turbulence.** Turbulence created as the result of friction with the surface of the earth causes a mixing process which moves the heated air to other areas of the atmosphere.
- **Compression.** There are instances where air masses are forced down, such as air moving down the leeward side of a mountain. The air pressure increases as the air mass moves further down, compressing the air mass. This compression forces the particles together, creating heat. This phenomenon is also called subsidence.

The Cooling Process

Since the atmosphere is heated from below, the temperature usually decreases with altitude. The rate of temperature change is known as a lapse rate. The lapse rate is only a guideline as there is a variation in air masses and cooling processes. The following are three main cooling processes:

- **Radiation Cooling.** At night the temperature of the earth decreases with terrestrial radiation and cools the air in contact with the ground. Radiation cooling only affects the lower few thousand feet of the atmosphere.
- **Advection Cooling.** Air from a warm region moves over a cold region and cools the air.
- **Adiabatic Process.** As air is warmed it will begin to rise and as it rises it will expand and cool. In a rising current of air, the temperature decreases at a rate that is entirely independent of the surrounding, non-rising air.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. How is the atmosphere heated?

Q2. Identify the four heating processes.

Q3. Identify the three cooling processes.

ANTICIPATED ANSWERS

A1. The atmosphere is heated from below not from above.

A2. Convection, advection, turbulence, and compression.

A3. Radiation cooling, advection cooling, and adiabatic process.

Teaching Point 3	Describe the Effects of Temperature on Relative Humidity
Time: 10 min	Method: In-Class Activity

THE EFFECTS OF TEMPERATURE ON RELATIVE HUMIDITY

Temperature will affect the relative humidity of an air mass by changing the volume of the air mass.

As the temperature of the air mass increases, the air mass will expand increasing the volume of the mass. The result is that the relative humidity will decrease, as the air mass has a higher capacity for water. This assumes that there is no change in the amount of water in the air mass.

As the temperature of the air mass decreases, the air mass will contract, decreasing the volume of the mass. The result is that the relative humidity will increase, as the air mass has a lower capacity for water. This assumes that there is no change in the amount of water in the air mass.

ACTIVITY

OBJECTIVE

The objective of this activity is to illustrate the effects of temperature on relative humidity.

RESOURCES

- Water,
- Paper towel,
- One small plastic cup per cadet, and
- One large plastic cup per cadet.

ACTIVITY LAYOUT

N/A.

ACTIVITY INSTRUCTIONS

1. Distribute one small cup and one large cup to each cadet.
2. Fill each small cup three quarters full of water. This will represent an air mass with a relative humidity of 75 percent.
3. Have the cadet pour the water from the small cup into the large cup. The large cup represents the results of increasing the temperature of the air mass.
4. Have the cadets estimate the percentage of the large cup which now contains water.
5. Fill the large cup of water to 80 percent. This will represent the continued evaporation of water from all sources into the air mass.
6. Have the cadets pour the large cup into the small cup. This will represent the results of cooling the air mass to the dew point. The water that does not fit into the small cup is the precipitation.
7. Have the cadets clean up the water.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 3

The cadets' participation in the relative humidity activity will serve as the confirmation of this TP.

Teaching Point 4	**Explain the Effects of Temperature and Humidity on Weather**
Time: 5 min	Method: Interactive Lecture

THE EFFECTS OF TEMPERATURE AND HUMIDITY ON WEATHER

Temperature and humidity have a major effect on the weather. Together they will determine cloud formation and precipitation.

Dew Point

The temperature of the air mass will change during the heating and cooling processes. As the temperature nears the dew point, the air will become more saturated. This increases the relative humidity and allows clouds to form.

Relative Humidity

As the relative humidity increases, the weight of the air mass also increases. When the dew point is reached, the air will become saturated, and clouds will form. Once the air mass has reached 100 percent relative humidity, any addition of water or drop in temperature will cause precipitation.

Precipitation

Precipitation may be solid or liquid, depending on the temperature of the air mass. Snow will occur if the air mass has a temperature below freezing. Rain will occur in an air mass which has a temperature above freezing. The temperature in the air mass will change with altitude, so that the water may freeze at higher levels of the air mass. Frozen precipitation such as hail and even snow has been seen in the summer months.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS

Q1. What is the effect of dew point on weather?

Q2. How does relative humidity affect the creation of precipitation?

Q3. How is it possible for hail or snow to occur in the summer months?

ANTICIPATED ANSWERS

A1. As the temperature nears the dew point, the air will become more saturated.

A2. Once the air mass has reached 100 percent relative humidity, any addition of water or drop in temperature will cause precipitation.

A3. The temperature in the air mass will change with altitude, so water may freeze at higher levels of the air mass.

Teaching Point 5	**Explain Types of Precipitation**
Time: 10 min	Method: Interactive Lecture

TYPES OF PRECIPITATION

Show slides of figures located at Annex Q.

There are seven main categories of precipitation listed by the World Meteorological Organization (WMO). Each one is created depending on temperature and cloud type. Types of precipitation include:

- **Drizzle.** Precipitation in the form of small water droplets which appear to float. In temperatures near freezing, water droplets may freeze on contact with objects. This is known as freezing drizzle.

- **Rain.** Precipitation in the form of large water droplets. Freezing rain will occur when water droplets, which have retained their liquid form in freezing conditions, make contact with an object and freeze.
- **Hail.** Formed in clouds, which have strong vertical currents (such as thunderstorms), hail is the result of a water droplet which has been prevented from exiting the cloud by the vertical currents, until it has reached a particular mass. The stronger the vertical currents, the larger the hailstones. Softball-sized hailstones have been seen in the Prairies and tropical areas, where large thunderstorms commonly occur. The hailstone in Figure 13-4-1 has a circumference of 47.63 cm (18.75 inches) and weighs almost 1 kg (2 pounds).

UCAR Communications, Staff Notes Monthly, 2003, One Hail of a Storm, Copyright 2003 by University of Carolina. Retrieved April 2, 2008, from http://www.ucar.edu/communications/staffnotes/0308/hail.html

Figure 13-4-1 Hailstone

- **Snow Pellets.** If the water region where the cloud is receiving water from is shallow, then the droplet will not form the hard shell that a hailstone would have. The pellet falls as a soft pellet of snow.

Climber.org, by S. Eckert, 2006. Graupel–Snow Pellets, Lighter and Smaller Than Hail, Copyright 2006 by Climber.org. Retrieved April 2, 2008, from http://www.climber.org/TripReports/2006/1473.html

Figure 13-4-2 Snow Pellets

- **Snow.** Snow is the result of sublimation. Flakes are an agglomeration of ice crystals and are usually in the shape of a hexagon or star.

Neatorama, 2007, Snow-donut. Copyright 2007 by Neatorama. Retrieved April 2, 2008, from http://www.neatorama.cachefly.net/images/2007-03/snow-donut.jpg

Figure 13-4-3 Snow Doughnut

- **Ice Prisms.** Created in stable air masses at very low temperatures. Ice prisms are tiny ice crystals in the form of needles. They can form with or without clouds. Sometimes confused with ice fog.

Ohio Weather Library, by B. Plonka, 2008, Unusual Weather. Copyright 2008 by Ohio Weather Library. Retrieved April 2, 2008, from http://www.owlinc.org/unusualweatherpg7.html

Figure 13-4-4 Ice Prisms

- **Ice Pellets.** Ice pellets are raindrops, which are frozen before contacting an object (as opposed to freezing rain, which freezes after contact with an object). They generally rebound after striking the ground.

CONFIRMATION OF TEACHING POINT 5

QUESTIONS

Q1. What are the seven types of precipitation?

Q2. What process creates snow?

Q3. What is the difference between ice pellets and freezing rain?

ANTICIPATED ANSWERS

A1. Drizzle, rain, hail, snow pellets, snow, ice prisms and ice pellets.

A2. Sublimation.

A3. Ice pellets freeze before contacting an object while freezing rain freezes after contact.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. Define dew point.

Q2. Explain how the atmosphere is heated.

Q3. Explain the effect of dew point on weather.

ANTICIPATED ANSWERS

A1. Dew point is the temperature to which unsaturated air must be cooled, at a constant pressure, in order for it to become saturated.

A2. The atmosphere is heated from below not from above.

A3. As the temperature nears the dew point, the air will become more saturated.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-803/PG-001, Chapter 3, Annex B, Aviation Subjects – Combined Assessment PC.

CLOSING STATEMENT

Weather is an amazing aspect of nature, which has a great impact on how we live our lives. Being aware of what causes weather will assist cadets in making decisions about outdoors activities.

INSTRUCTOR NOTES/REMARKS

Video resources are available for purchase through flight training centres or aviation supply websites. These videos may be used to augment instruction.

REFERENCES

C3-116 (ISBN 0-9680390-5-7) MacDonald, A. F., & Peppler, I. L. (2000). *From the Ground Up: Millennium Edition*. Ottawa, ON: Aviation Publishers Co. Limited.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 5

EO C336.01 – READ AN AVIATION ROUTINE WEATHER REPORT (METAR)

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Gather sample METARs from the NavCanada aviation weather website.

Create a slide of Annex R.

Photocopy Annex S for each cadet.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for TPs 1 and 2 to introduce the cadets to a METAR.

An in-class activity was chosen for TP 3 as an interactive way for the cadets to practice reading a METAR.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have read a METAR.

IMPORTANCE

It is important for cadets to read a METAR as it will enable them to determine weather conditions for flying in the local area.

Teaching Point 1	**Describe a METAR**
Time: 10 min	Method: Interactive Lecture

Weather is a major factor in aviation. Pilots must constantly watch the weather around them as weather will effect the way an aircraft operates. In particular, pilots must review the weather prior to going flying to decide whether it is safe to fly.

Show the slide of examples located at Annex R.

DEFINITION

METAR is the name given to the international meteorological code used in aviation routine weather reports. These reports describe the existing weather conditions at a specific time and location. In other words, the METAR is a snapshot of the current weather; it is not a forecast.

FREQUENCY OF REPORTS

Normally, METAR observations are taken and disseminated on an hourly basis. METARs are only valid for the time that they are issued, not for the hour in between reports. METARS are normally issued every hour, on the hour as weather does not normally change much in an hour.

SPECIAL WEATHER REPORTS (SPECI)

There are times when the weather may change drastically in a short period of time. When this happens a SPECI is issued. SPECIs can be issued at any time. They will normally follow the last METAR issued and in sequence from oldest to newest as more SPECIs are issued. SPECIs use the same code as a METAR, but will start with SPECI.

WHERE METARS ARE AVAILABLE

METARs can be found at several locations. The three most common locations are:

- NavCanada's aviation weather website,
- a Flight Services Station (FSS),
- a Flight Information Centre (normally accessed by phone).

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. What does a METAR describe?

Q2. How often is a METAR observation normally issued?

Q3. Why is a SPECI issued?

ANTICIPATED ANSWERS

A1. The existing weather conditions at a specific time and location.

A2. METARS are normally issued every hour, on the hour.

A3. When the weather may change drastically in a short period of time.

Teaching Point 2 **Review Terminology Used in METARs**

Time: 25 min Method: Interactive Lecture

TERMINOLOGY USED IN METARS

Indicate on the slide of Annex R each of the following groupings as they are covered.

METAR is a code used in aviation weather reporting. This code is based on the World Meteorological Organization's (WMO) standards and conventions. A METAR is organized into sections with each section always showing in the same order.

Report Type

The report name is given in the first line of the text. The name will show as either METAR or SPECI.

Station Indicator

Each weather reporting station in Canada is assigned a four letter identifier, starting with the letter C. The remaining three letters are an abbreviation of the reporting station, where the first letter identifies what type of station it is.

An example would be CYOW for the reporting station at Ottawa/MacDonald-Cartier International Airport. The C means the station is Canadian, the Y means the station is co-located with an airport, and OW is the airport identifier.

Date and Time of Observation

The date and time of the observation are given in a six-digit grouping, based on universal coordinated time (UTC). The first two digits signify the day of the current month, while the last four digits signify the time of the day. The official time of the observation is given for all METAR reports that do not deviate more than 10 minutes from the top of the hour. SPECIs will have the time reported to the exact minute.

For example, a METAR will show as: 091000Z, which means that the observation was taken on the ninth day of the month at 1000 hrs UTC (or within 10 minutes of that hour).

For example, a SPECI will show as: 091036Z, which means that a significant change in weather was observed on the ninth day of the month at 1036 hrs UTC.

Report Modifier

This field may contain two possible codes: AUTO or CCA. AUTO indicates that the report is primarily based on observations from an automated weather observation station (AWOS). CCA is used to indicate corrected reports, where the first correction is CCA, the second is CCB, and so on. Both AUTO and CCA may be found in the same report.

Wind

This group reports the two-minute average wind direction and speed. Direction is always three digits, given degrees true but rounded off to the nearest 10 degrees. Speed is normally two digits, and is given in knots (nautical miles per hour or kt). A reading of 00000 kt indicates calm winds.

For example, 35016 will read as: winds are 350 degrees true (rounded off) at 16 kts.

If gust conditions exist, the direction and speed will be followed by a G and the maximum gust strength. A gust must be 5 knots stronger than the 10-minute average wind speed.

For example, 35016G25 will read as: winds are 350 degrees true at 16 kts gusting to 25 kts.

Prevailing Visibility

Prevailing visibility is the average visibility at the reporting station. The prevailing visibility is reported in statute miles (sm) or fractions of a statute mile.

Runway Visual Range

This is only included if the prevailing visibility is less than 1 sm, or the runway visual range is less than 6 000 feet. This group will start with an R, then the runway number (eg, 06) and position (eg, L for left, R for right, C for centre), followed by the runway visual range in hundreds of feet. This is based on a 10-minute average.

For example, R06L/1000V2400FT/U will read as: the minimum runway visual range for runway 06 left is 1 000 feet and the maximum is 2 400 feet with an upward trend.

Present Weather

This section indicates the current weather phenomena at the reporting station. This may include precipitation, obscuration, or other phenomena. This section will include all phenomena that exist, varying the length of the section between reports.

Each phenomenon is represented by a code, which may be two to nine characters in length. Each code may include one or both of the following prefixes:

- **Intensity.** (-) indicates light, (+) indicates heavy, and no symbol indicates moderate.
- **Proximity.** Used primarily with precipitation or tornadoes, VC will precede certain phenomena meaning that they are in the vicinity (5 sm) of the station, but not actually at the station.

Distribute the handout located at Annex S.

For example, VCFZRABLSN+SNVA would translate to: In the vicinity of the airport there is freezing rain, blowing snow, heavy snow, and volcanic ash.

The abbreviations used for present weather are a mixture of English and French root words. FZ comes from freezing, while BR comes from brumé (mist), and FU comes from fumée (smoke).

Sky Conditions

This group reports the sky condition for layers aloft. The group will include how much of the sky is covered measured in oktas (eighth of the sky) and the height of the clouds in hundreds of feet above ground level (AGL). The sky cover is represented by an abbreviation related to how many oktas of the sky are covered.

- SKC = sky clear, no cloud present.
- FEW = few, greater than zero to two eighths cloud cover.
- SCT = scattered, three eighths to four eighths cloud cover.
- BKN = broken, five eighths to less than eight eighths cloud cover.
- OVC = overcast, eight eighths cloud cover.
- CLR = clear, clear below 10 000 feet AGL.

Cloud height is represented by a three digit number, which when multiplied by one hundred equals the actual height AGL. There will be one entry for every layer of cloud.

For example, SCT025 would translate to: scattered cloud at 2 500 feet AGL.

Temperature and Dewpoint

This group reports the air temperature and dewpoint temperature, rounded to the nearest whole degree Celsius. A negative value will be preceded by (M). A (/) will separate the two values.

Altimeter Setting

This group reports the altimeter setting at the reporting station in inches of mercury. The group starts with (A), which will be followed by four digits, which directly relate to the actual value of the altimeter setting. Place a decimal after the second digit in order to read this group.

For example, A3006 would translate to: altimeter setting is 30.06 inches of mercury.

Remarks

This group will usually include cloud types in each layer as well as opacity, general weather remarks, and sea level pressure measured in hectopascals. The sea level pressure will always be the last entry in a METAR, prefaced by SLP. Sea level pressure is translated by either adding a 9 or a 10 in front of the value given. The goal is to make the number as close to 1 000 as possible.

For example, SLP 123 would translate to: sea level pressure is 1012.3 hPa.

For example, SLP 998 would translate to: sea level pressure is 999.8 hPa.

SLP actually represents the station pressure or the theoretical sea level pressure at the reporting station.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. How are date and time expressed in a METAR?

Q2. What does the present weather section indicate?

Q3. What is the last entry of a METAR?

ANTICIPATED ANSWERS

A1. The date and time of the observation are given in a six-digit grouping, based on universal coordinated time (UTC).

A2. This section indicates the current weather phenomena at the reporting station.

A3. The sea level pressure will always be the last entry in a METAR.

Teaching Point 3	**Demonstrate and Have the Cadets Read a METAR**
Time: 15 min	Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is for the cadets to read a METAR.

RESOURCES

Five or six examples of METARs.

ACTIVITY LAYOUT

Arrange the classroom to enable both individual and small-group work.

ACTIVITY INSTRUCTIONS

1. Project a sample METAR and demonstrate reading it.
2. Distribute examples of METARs.
3. Have the cadets work in pairs to decipher a METAR in three minutes.
4. Correct the cadets’ work.
5. Have the cadets work in pairs to decipher a second METAR in two minutes.
6. Correct the cadets’ work.
7. Repeat Steps 5. and 6. as often as possible until examples are exhausted.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 3

The cadets’ participation in the METAR reading activity will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets’ participation in reading METAR will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Reading a METAR is a skill which can be transferred to many other outdoor activities. The code used may also be found in aviation forecasts, which cover larger areas. This can be used for camping trips, trip planning and checking to see if your flight the next morning will be delayed.

INSTRUCTOR NOTES/REMARKS

Recent METARs can be found at http://www.flightplanning.navcanada.ca/cgi-bin/CreePage.pl?Langue=anglais &NoSession=NS_Inconnu?Page=forecast-observation&TypeDoc=html. Click on the METAR/TAF icon and then enter the airport name or identifier.

REFERENCES

C2-044 Transport Canada. (2007). *Aeronautical Information Manual*. Retrieved October 2, 2007, from http://tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF.

C3-116 (ISBN 0-9680390-5-7) MacDonald, A. F., & Peppler, I. L. (2000). *From the Ground Up: Millennium Edition*. Ottawa, ON: Aviation Publishers Co. Limited.

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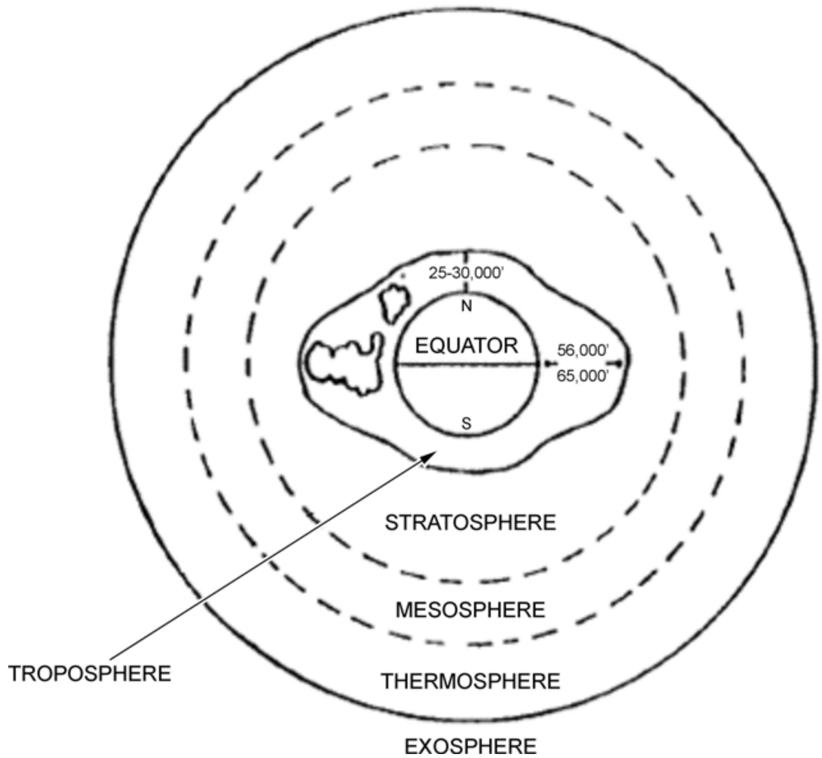
DIVISIONS OF THE ATMOSPHERE



A. F. MacDonald and I. L. Peppler, From the Ground Up, Aviation Publishers Co. Limited (p. 123)

Figure 13A-1 The Four Layers of the Atmosphere

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CUMULUS CLOUD

"Victoria Weather", by UVic, School-Based Weather Station Network. Retrieved November 1, 2007, from http://www.victoriaweather.ca/clouds

Figure 13B-1 Cumulus Cloud

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STRATUS CLOUD

"Victoria Weather", by UVic, School-Based Weather Station Network. Retrieved November 1, 2007, from http://www.victoriaweather.ca/clouds

Figure 13C-1 Stratus Cloud

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COMMON CLOUDS

Cloud Name	Cloud Family	Cloud Description
Cirrus	High	High, thin, wispy clouds blown by high winds into long streamers. Cirrus clouds usually move across the sky from west to east. They generally indicate pleasant weather.
Cirrocumulus	High	Appears as small, round white puffs. The small ripples in the cirrocumulus sometimes resemble the scales of a fish. A sky with cirrocumulus clouds is sometimes referred to as a “mackerel sky”.
Altocumulus	Middle	Appear as grey, puffy masses, sometimes in parallel waves or bands. The appearance of these clouds on a warm, humid summer morning often means thunderstorms will occur by late afternoon.
Altostratus	Middle	A grey or blue-grey layer cloud that typically covers the entire sky. In the thinner areas of the cloud, the sun may be dimly visible as a round disk. This cloud appears lighter than stratus clouds.
Stratus	Low	Uniform grey layer cloud that often covers the entire sky. They resemble fog that does not reach the ground. Usually no precipitation falls from stratus clouds, but sometimes they may drizzle.
Nimbostratus	Low	Dark grey layer clouds associated with continuously falling rain or snow. They often produce precipitation that is usually light to moderate.
Stratocumulus	Low	A series of round mass that form a layer cloud. This type of cloud is usually thin enough for the sky to be seen through breaks.
Cumulus	Vertical Development	Puffy clouds, which are thick, round, and lumpy. They sometimes look like pieces of floating cotton. They usually have flat bases and round tops.
Cumulonimbus	Vertical Development	Thunderstorm clouds that form if cumulus clouds continue to build. Violent vertical air currents, hail, lightning, and thunder are associated with the cumulonimbus clouds.

Director Cadets 3, 2007, Ottawa, ON: Department of National Defence

Figure 13D-1 Common Clouds

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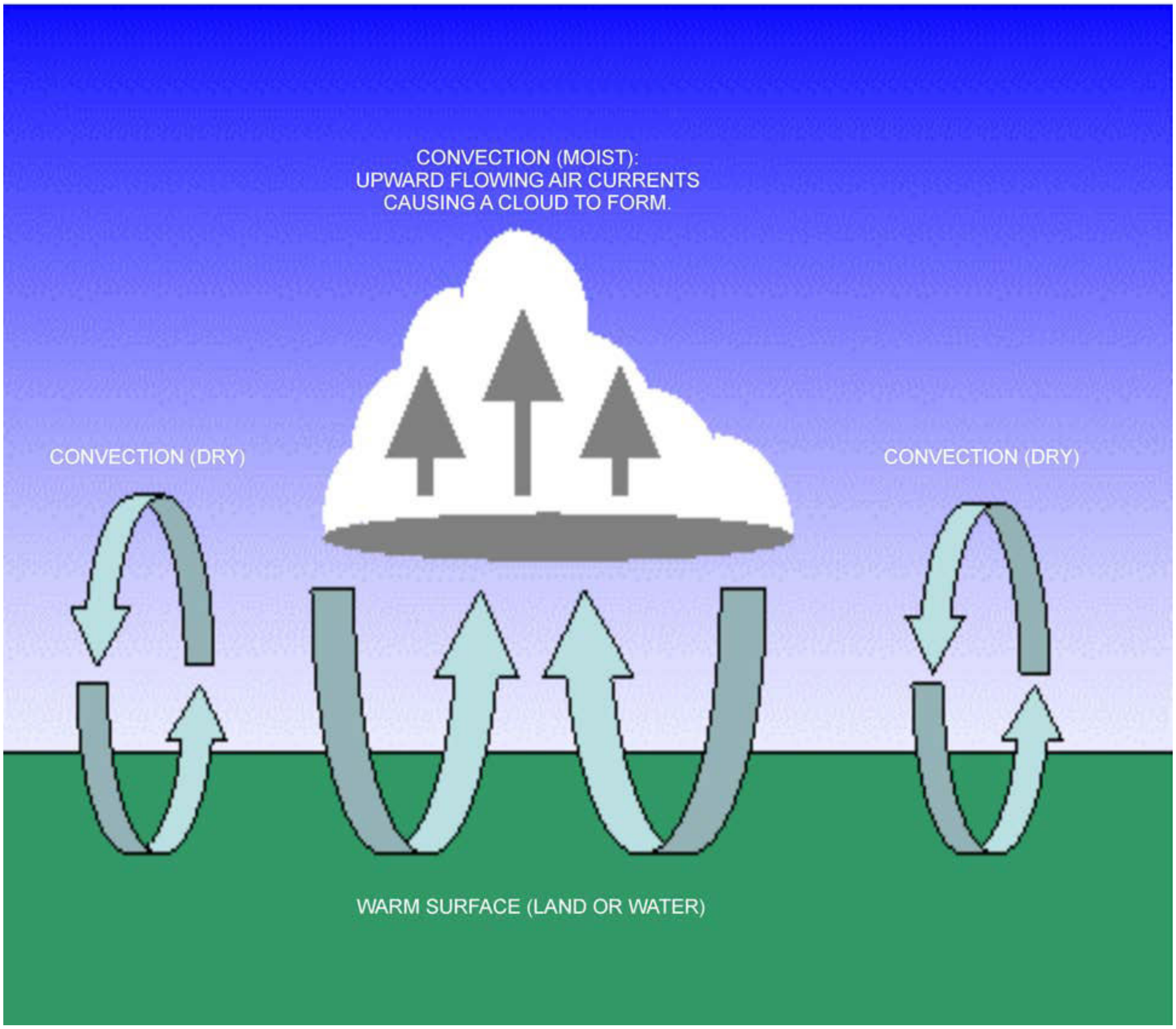
CONVECTION



WeatherQuestions.com, 2007, What is Convection. Copyright 2007 by WeatherStreet. Retrieved March 17, 2008, from http://www.weatherquestions.com/What_is_convection.htm

Figure 13E-1 Convection

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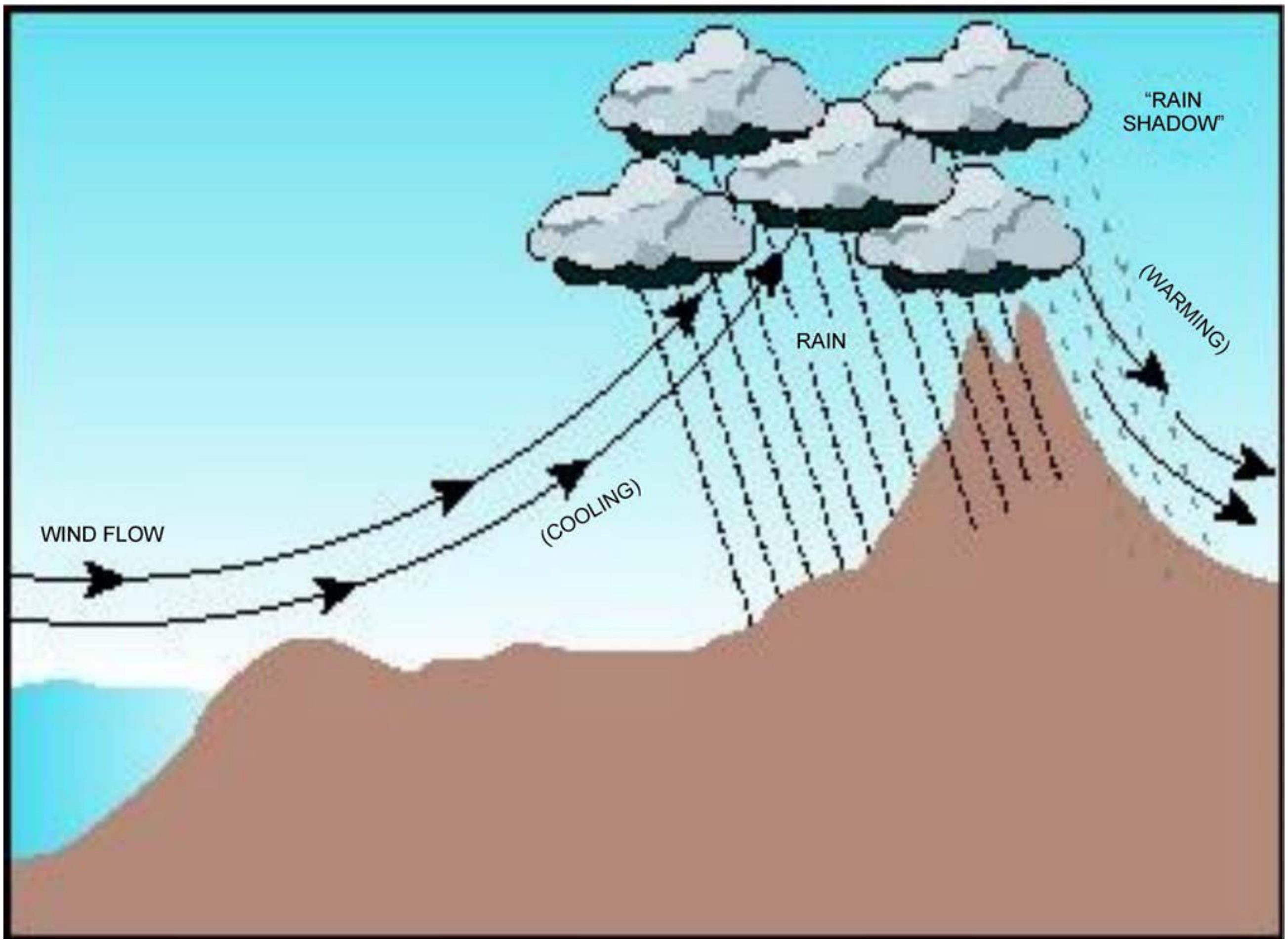
OROGRAPHIC LIFT



Water Encyclopedia, by G. H. Taylor, 2007, Water as a Climate Moderator. Copyright 2007by Advameg. Retrieved March 17, 2008, from http://www.waterencyclopedia.com/Ce-Cr/Climate-Moderator-Water-as-a.html

Figure 13F-1 Orographic Lift

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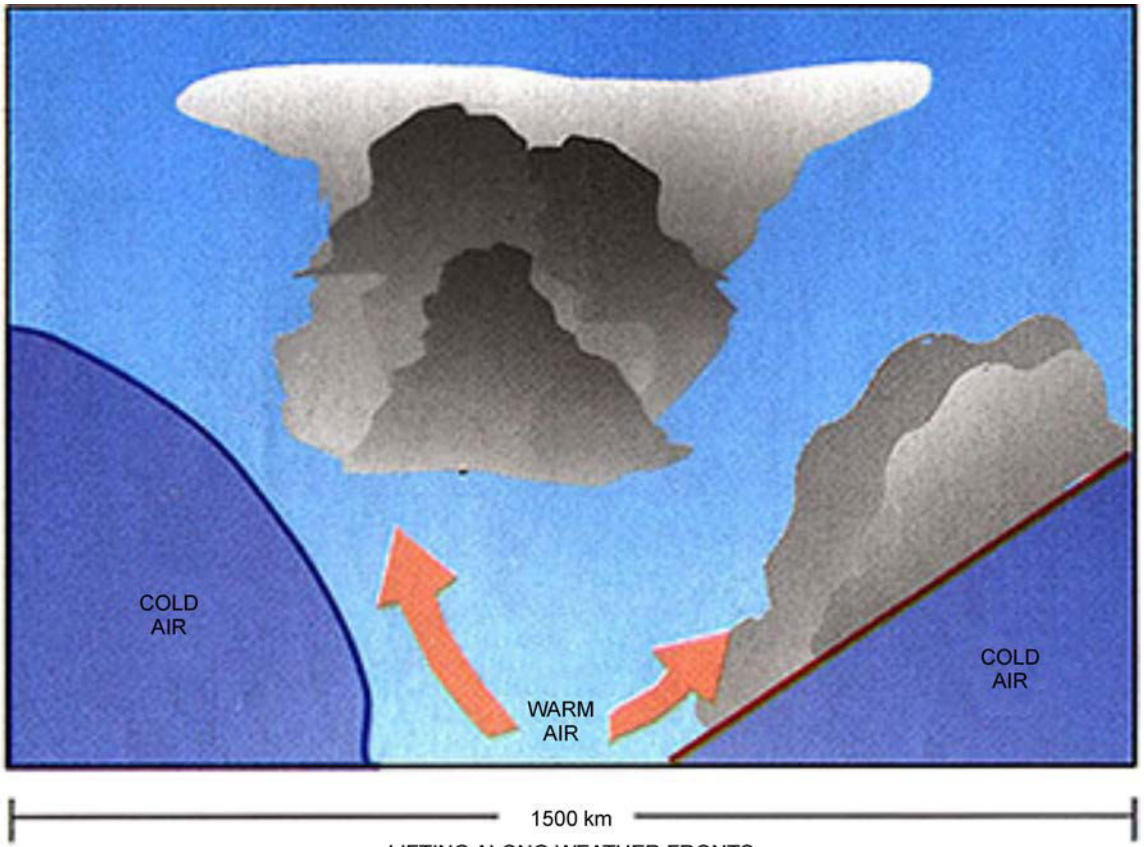
FRONTAL LIFT



Federation of American Scientists, by N. M. Short, Sr, 2007, Atmospheric Circulation: Weather Systems. Copyright 2007 by FAS. Retrieved March 17, 2008, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

Figure 13G-1 Frontal Lift

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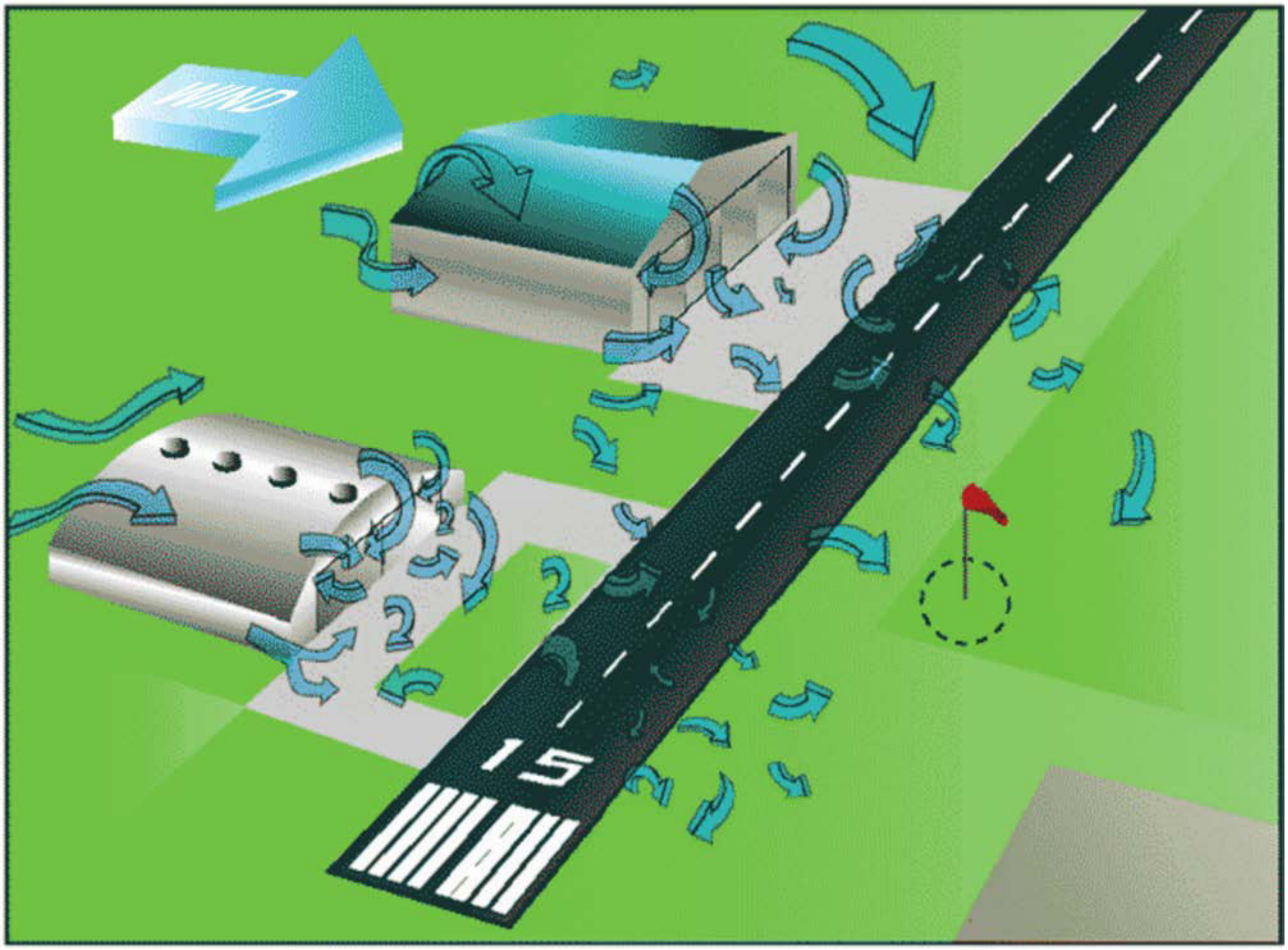
MECHANICAL TURBULENCE: MAN-MADE



Free Online Private Pilot Ground School, 2006, Aviation Weather–Principles. Copyright 2006. Retrieved March 17, 2008, from http://www.free-online-private-pilot-ground-school.com/Aviation-Weather-Principles.html

Figure 13H-1 Mechanical Turbulence: Man-Made

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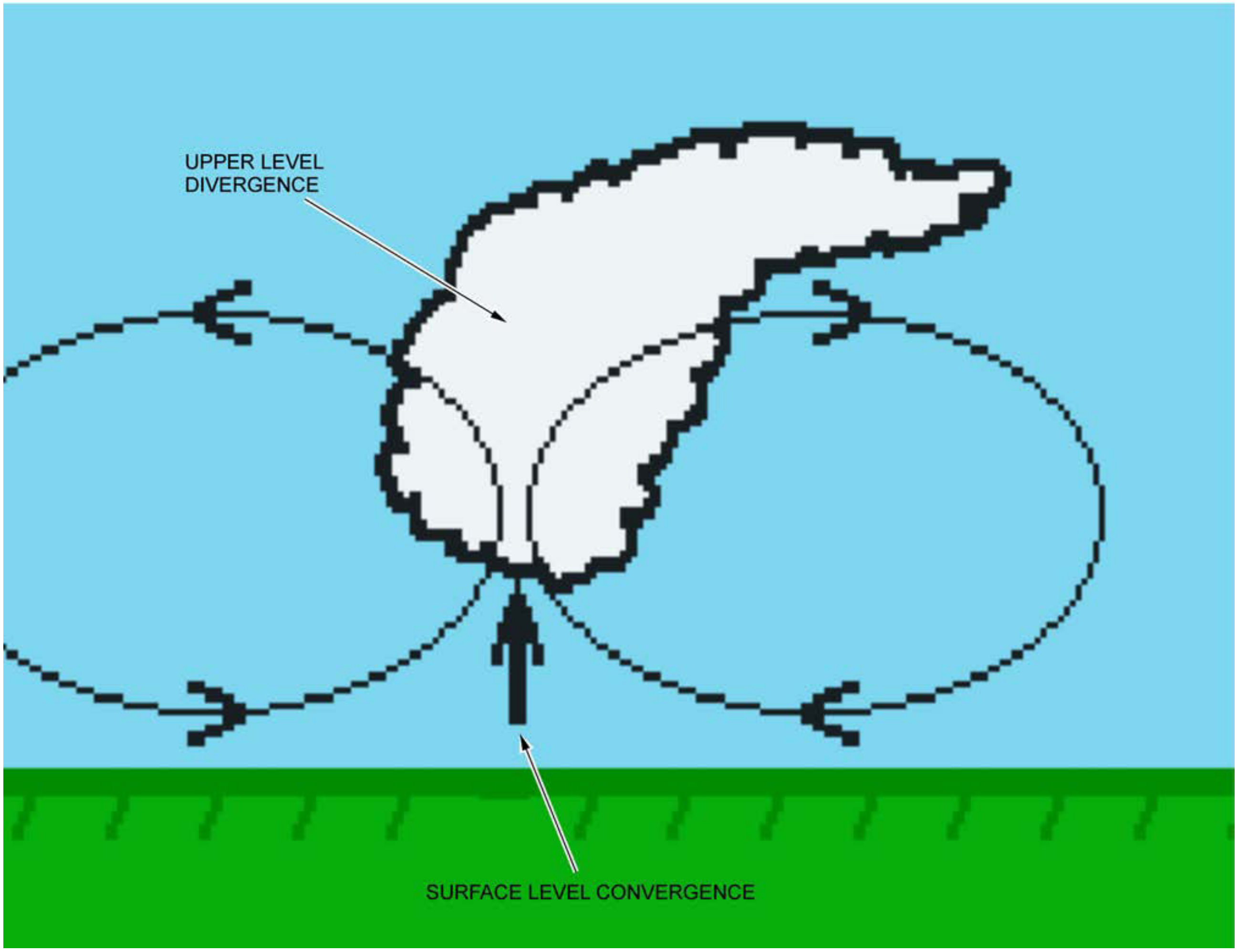
CONVERGENCE



The Weather Doctor, by K. C. Heidron, PhD, 2002, What Goes Up: Part 3 Convergence and Divergence. Retrieved March 17, 2008, from http://www.islandnet.com/~see/weather/elements/whatgoesup3.htm

Figure 13I-1 Convergence

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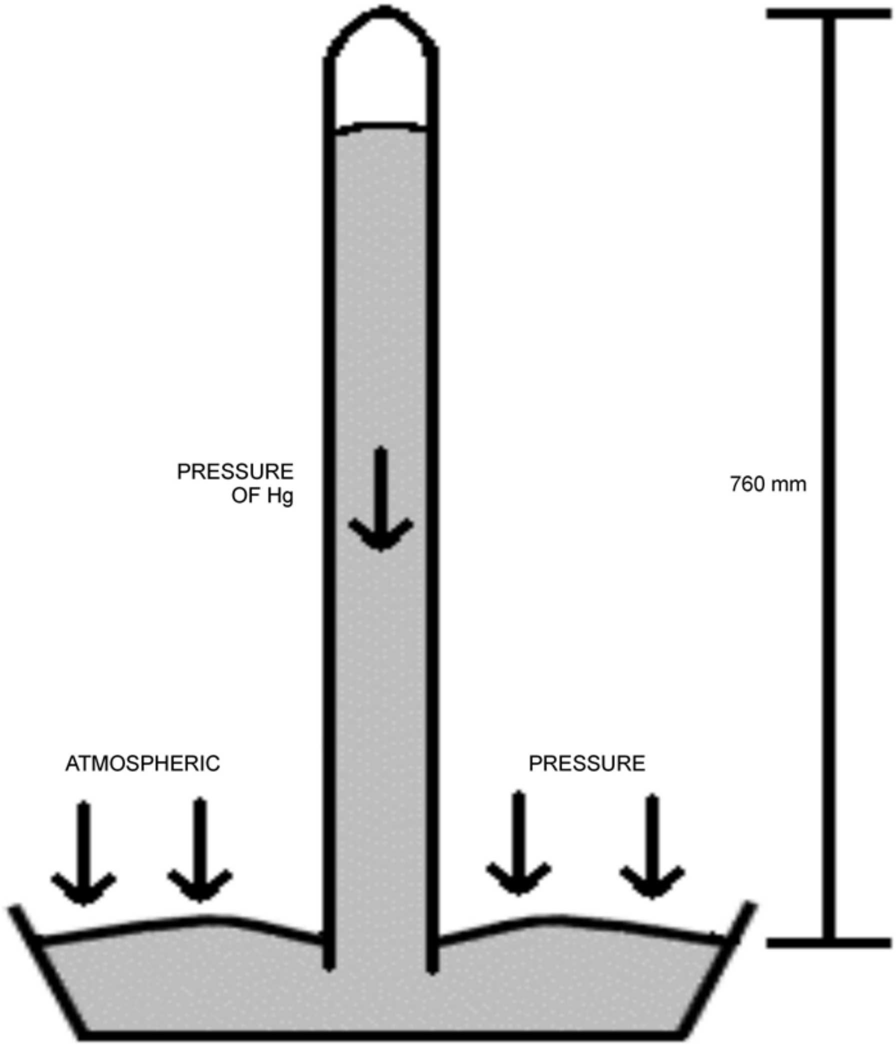
BAROMETER



$P_{atm} = P_{Hg}$

Chemistry Tutorial Notes, Department of Chemistry, Texas A&M University, 2006, Properties of Gases, Copyright 2006 by Texas A&M University. Retrieved April 4, 2008 from http://www.chem.tamu.edu/class/majors/tutorialnotefiles/pressure.htm

Figure 13J-1 Barometer

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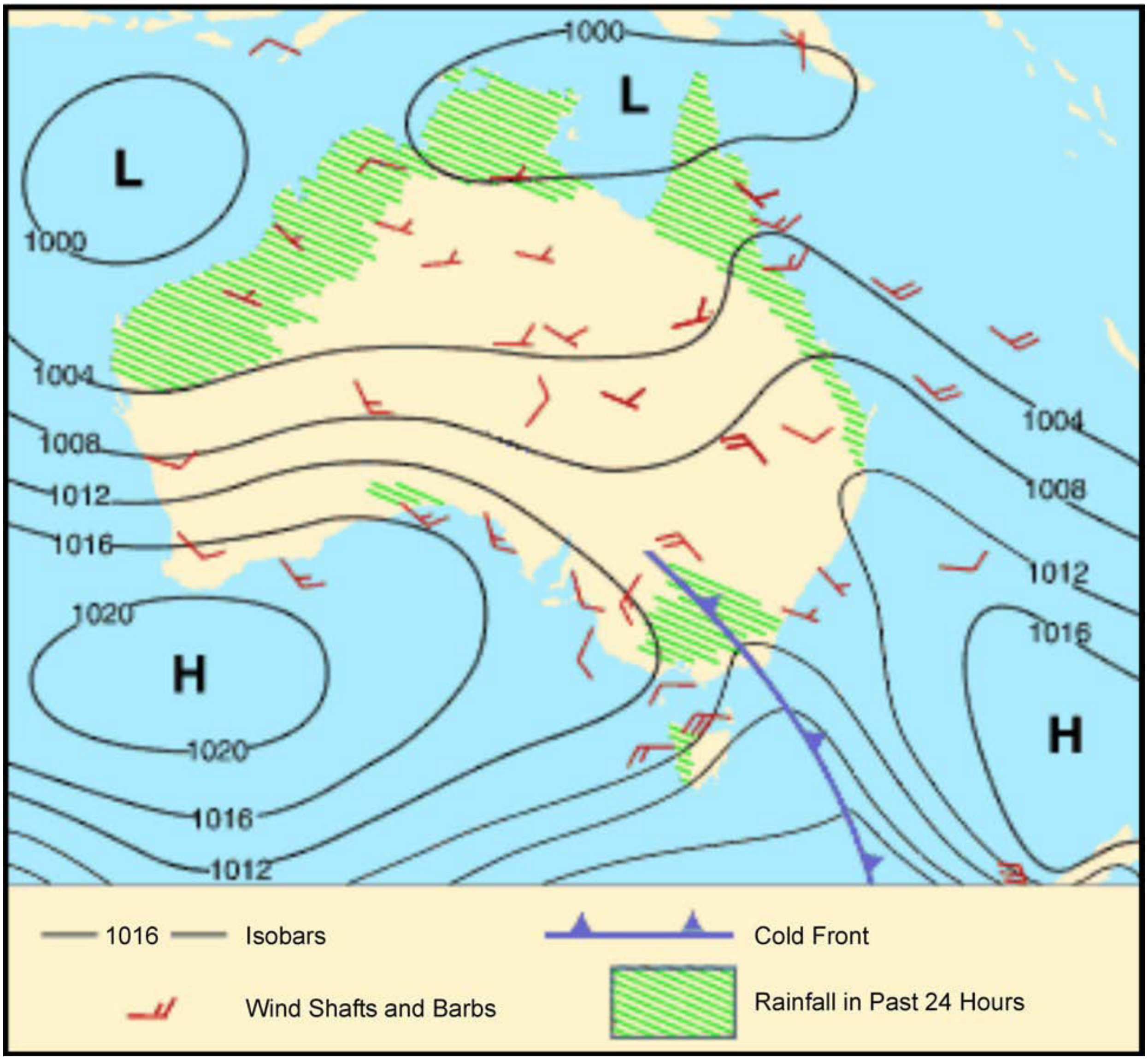
ISOBARS ON A WEATHER MAP



Australian Government, Bureau of Meteorology, 2008, Air Masses and Weather Maps, Copyright 2008 by Commonwealth of Australia, Bureau of Meteorology. Retrieved April 7, 2008 from http://www.bom.gov.au/info/ftweather/page_7.shtml

Figure 13K-1 Isobars on a Weather Map

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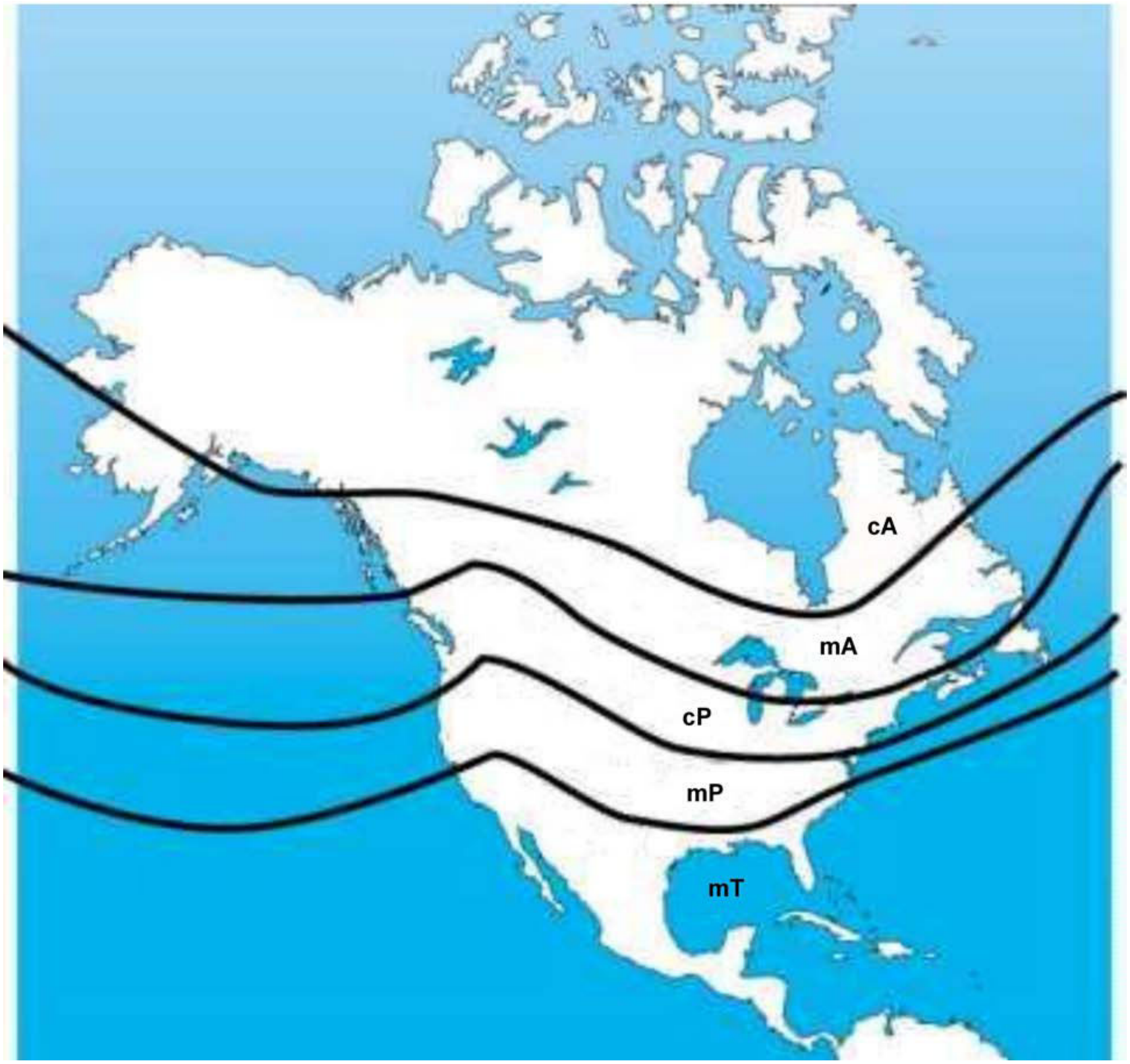
NORTH AMERICAN AIR MASSES



Meteorological Service of Canada, 2004, Frontal Systems, Copyright 2004 by Environment Canada. Retrieved April 7, 2008 from http://www.qc.ec.gc.ca/meteo/Documentation/Front_e.html

Figure 13L-1 North American Air Masses

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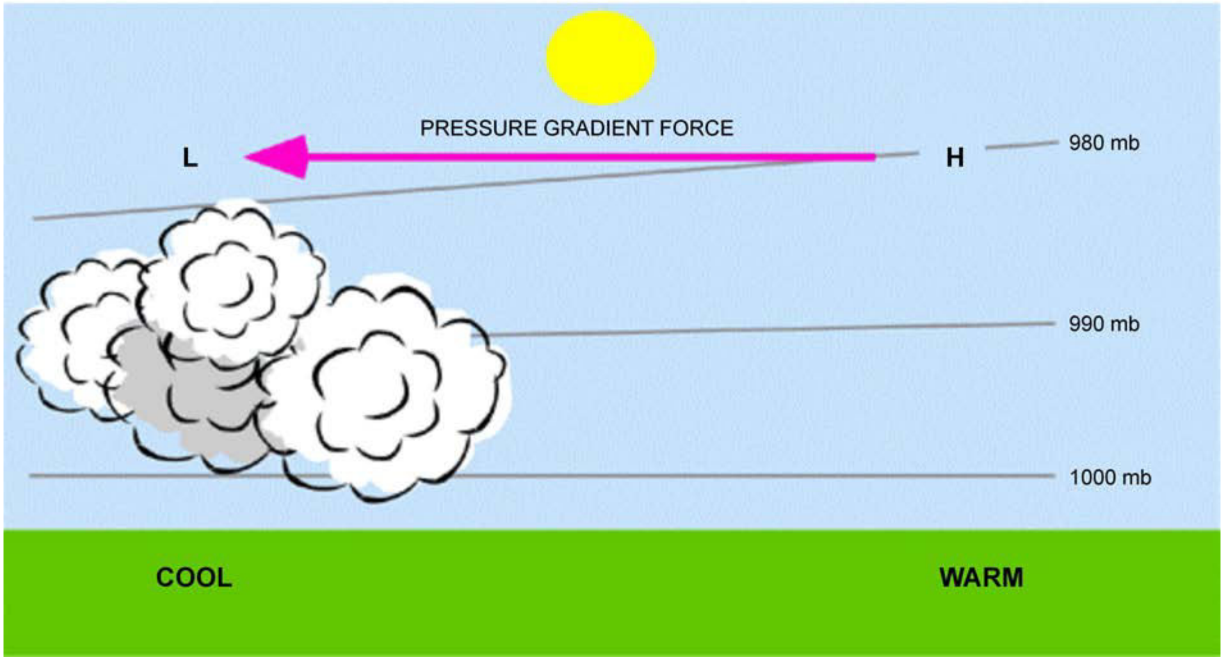
PRESSURE GRADIENT



PhysicalGeography.net, Dr. M. Pidwirny, University of British Columbia Okanagan, 2007, Introduction to the Atmosphere, Copyright 2007 by M. Pidwirny. Retrieved April 7, 2008 from http://www.physicalgeography.net/fundamentals/7o.html

Figure 13M-1 Pressure Gradient

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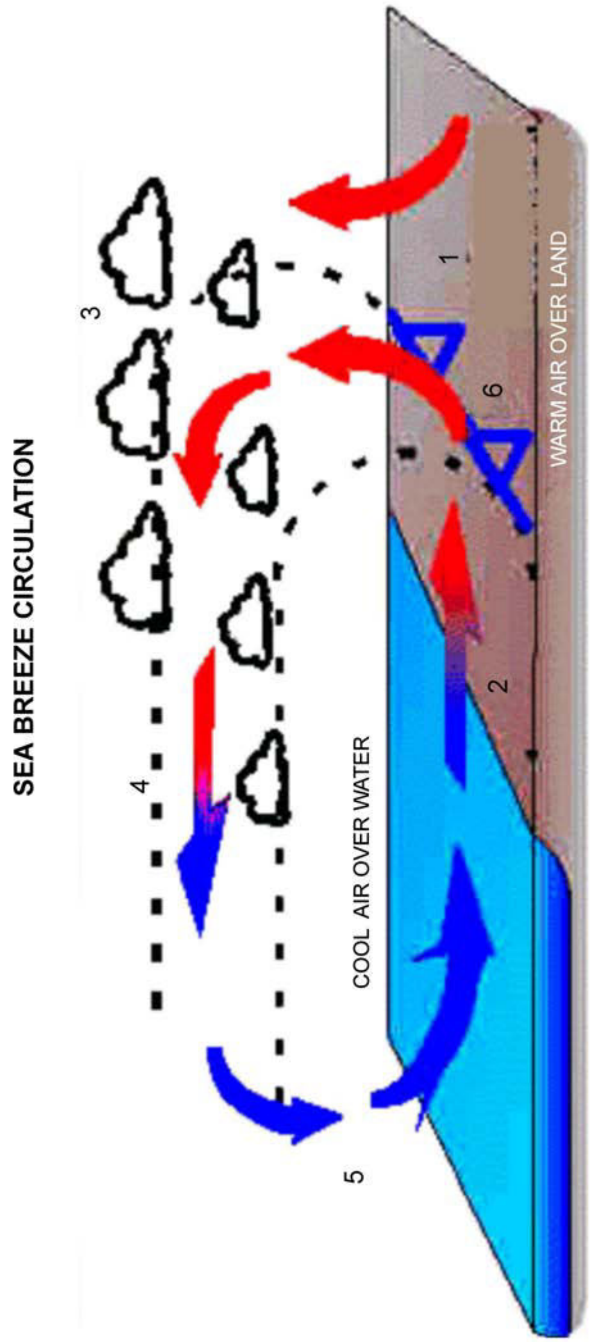
SEA BREEZE



The Weather Doctor, K. C. Heidron, PhD, 1993, Sea and Land Breezes, Copyright 1998 by K. C. Heidron PhD. Retrieved April 7, 2008 from http://www.islandnet.com/~see/weather/elements/seabrz.htm

Figure 13N-1 Sea Breeze

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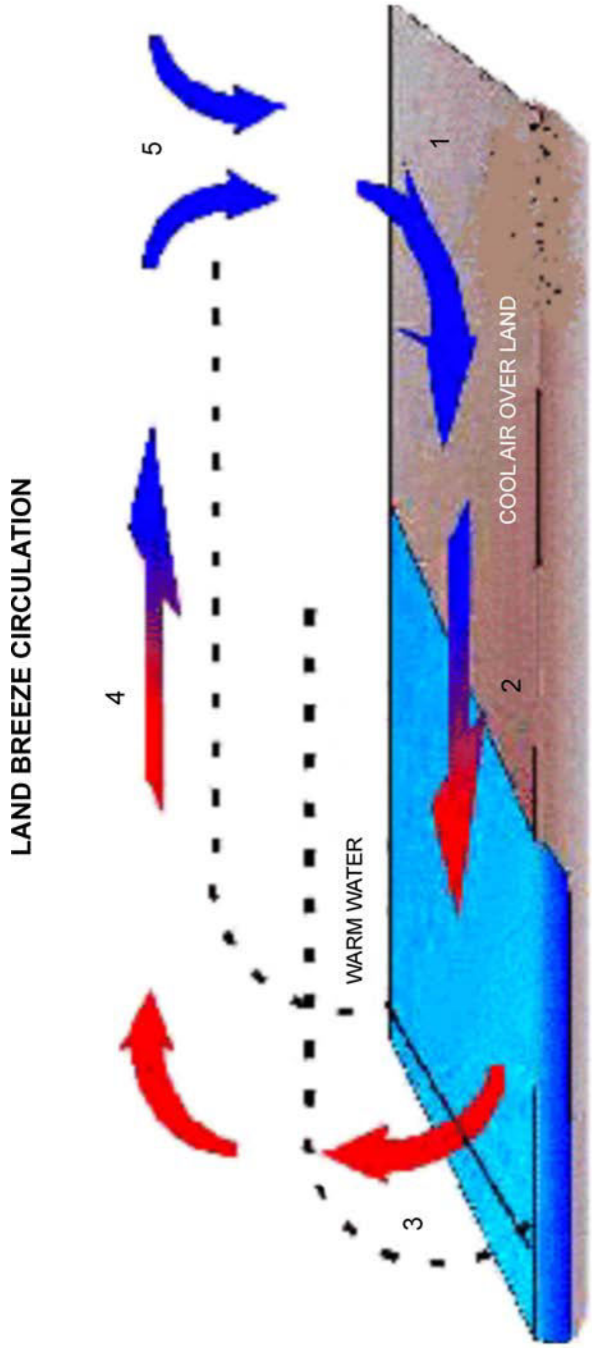
LAND BREEZE



The Weather Doctor, K. C. Heidron, PhD, 1993, Sea and Land Breezes, Copyright 1998 by K. C. Heidron PhD. Retrieved April 7, 2008 from http://www.islandnet.com/~see/weather/elements/seabrz.htm

Figure 13O-1 Land Breeze

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DEFINITIONS

Atmospheric Pressure. The pressure of the atmosphere at any point due to the weight of the overlying air.

Isobars. Areas of like pressure are joined by lines called isobars (from Greek *isos* [same] and *baros* [weight]).

Low Pressure Areas. Low pressure areas (often called lows, cyclones, or depressions) are areas of relatively lower pressure, with the lowest pressure in the centre.

High Pressure Areas. High pressure areas (often called anti-cyclones) are areas of relatively higher pressure, with the highest pressure in the centre.

Continental Air Mass. Air mass will be dry as it formed over land.

Maritime Air Mass. Air mass will be moist as it formed over water.

Arctic Air Mass. Air mass will be cold as it formed over the Arctic.

Polar Air Mass. Air mass will be cool as it formed over the Polar region.

Tropical Air Mass. Air mass will be warm as it formed over the Tropical region.

Wind. The horizontal movement of air within the atmosphere.

Pressure Gradient. The rate of change of pressure over a given distance measured at right angles to the isobars.

Sea Breeze. Occurs during the day when the land heats up more rapidly than the water.

Land Breeze. Occurs at night when the land cools down faster than the water.

Diurnal Variation. This is due to the heating processes which occur during the day, creating vertical currents and pressure gradients. At night, when the heating processes cease, the vertical currents diminish and the pressure gradients become shallower.

Coriolis Force. The rotation of the earth causes a deflection to the right (in the northern hemisphere). Coriolis Force also explains why air moves clockwise around a high, and counter-clockwise around a low pressure system.

Veering and Backing. Veering is a change in wind direction clockwise relative to the cardinal points of a compass while backing is a change in wind direction counter-clockwise caused by friction with the earth’s surface.

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TYPES OF PRECIPITATION

UCAR Communications, Staff Notes Monthly, 2003, One Hail of a Storm, Copyright 2003 by University of Carolina. Retrieved April 2, 2008, from http://www.ucar.edu/communications/staffnotes/0308/hail.html

Figure 13Q-1 Hailstone

Climber.org, by S. Eckert, 2006, Graupel–Snow Pellets, Lighter and Smaller Than Hail, Copyright 2006 by Climber.org. Retrieved April 2, 2008, from http://www.climber.org/TripReports/2006/1473.html

Figure 13Q-2 Snow Pellets

Neatorama, 2007, Snow-donut. Copyright 2007 by Neatorama. Retrieved April 2, 2008, from http://www.neatorama.cachefly.net/images/2007-03/snow-donut.jpg

Figure 13Q-3 Snow Doughnut

Ohio Weather Library, B. Plonka, 2008. Unusual Weather. Copyright 2008 by Ohio Weather Library. Retrieved April 2, 2008 from http://www.owlinc.org/unusualweatherpg7.html

Figure 13Q-4 Ice Prisms

SAMPLE METAR AND SPECI

METAR CYHZ 111700Z 28009G16KT 15SM FEW250 00/M11 A2990 RMK CS0 SLP134=

METAR CYHZ 111800Z 29015KT 15SM FEW250 01/M10 A2989 RMK CI0 SLP128=

METAR CYHZ 111900Z 30008KT 15SM FEW250 02/M12 A2987 RMK CI0 SLP123=

SPECI CYYJ 111744Z CCA 23019G24KT 20SM -SHRA BKN014 BKN030 BKN120 09/07 RMK SC5SC1AC1=

SPECI CYYJ 111744Z 23019G24KT 20SM -RA BKN014 BKN030 BKN120 09/07 RMK SC5SC1AC1=

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WORLD METEOROLOGICAL ORGANIZATION CODE FOR PRESENT WEATHER

QUALIFIER					WEATHER PHENOMENA			
INTENSITY or PROXIMITY 1	**DESCRIPTOR 2**		**PRECIPITATION 3**		**OBSCURATION 4**		**OTHER 5**	
Note: Precipitation intensity refers to all forms combined.	**MI**	Shallow	**DZ**	Drizzle	**BR**	Mist (Vis ≥ 5/8 SM)	**PO**	Dust/sand Whirls (Dust Devils)
	BC	Patches	**RA**	Rain	**FG**	Fog (Vis < 5/8 SM)	**SQ**	Squalls
	PR	Partial	**SN**	Snow	**FU**	Smoke (Vis ≤ 6 SM)	**+FC**	Tornado or Waterspout
	DR	Drifting	**SG**	Snow Grains				
- Light	**BL**	Blowing	**IC**	Ice Crystals (Vis = 6 SM)	**DU**	Dust (Vis ≤ 6 SM)	**FC**	Funnel Cloud
	SH	Shower(s)						
Moderate (no qualifier)	**TS**	Thunderstorm	**PL**	Ice Pellets	**SA**	Sand (Vis ≤ 6 SM)	**SS**	Sandstorm (Vis < 5/8 SM) (+SS Vis < 516 SM)
			GR	Hail				
+Heavy	**FZ**	Freezing	**GS**	Snow Pellets	**HZ**	Haze (Vis ≤ 6 SM)	**DS**	Dust storm (Vis < 5/8 SM) (+DS Vis < 516 SM)
VC In the vicinity			**UP**	Unknown precipitation (AWOS only)	**VA**	Volcanic Ash (with any visibility)		

Transport Canada, Aeronautical Information Manual, Transport Canada (p. 145)

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CHAPTER 14

PO 337 – DEMONSTRATE AIR NAVIGATION SKILLS

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 1

EO M337.01 – MEASURE DISTANCE ALONG A ROUTE

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create a slide of the terms located at Annex A.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for TPs 1 and 2 to introduce basic air navigation terms and types of air navigation.

Demonstration and performance was chosen for TP 3 as it allows the instructor to explain and demonstrate measuring distances while providing an opportunity for the cadet to practice this skill under supervision.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have measured distance along a route.

IMPORTANCE

It is important for cadets to learn to measure distance along a route since it is an important skill in all types of navigation. Cadets may travel and being able to determine the distance between points is important. A cadet who continues with flight training will use this skill during flight planning.

Teaching Point 1 | **Define Air Navigation Terms**

Time: 5 min | Method: Interactive Lecture

AIR NAVIGATION TERMS

Show the slide of the terms located at Annex A.

There are several key terms that must be understood.

Graticule. A three-dimensional geometrical pattern of intersecting circles. Envision the black lines on a basketball, or a globe with only the black lines.

Latitude. Parallels of latitude are imaginary circles on the earth's surface, which lie parallel to the equator. Latitude measures 90 degrees north and 90 degrees south of the equator. Parallels of latitude make up half of the earth's graticule. Latitude is measured in degrees (°), minutes ('), and seconds (").

Longitude. Meridians of longitude are imaginary circles on the earth's surface, which intersect at the true or geographic poles, and join the poles of the earth together. Longitude measures 180 degrees west and 180 degrees east of the prime meridian (0 degrees), which passes through Greenwich, England. Meridians of longitude make up the other half of the earth's graticule. Longitude is measured in degrees (°), minutes ('), and seconds (").

Nautical Miles. A nautical mile (nm) is 6 080 feet and is the average length of one minute of latitude.

Statute Miles. A statute mile is 5 280 feet.

Scale. Scale on a map is the relationship between a unit of distance on the chart to the distance on the earth that the unit represents. For example, a scale of 1 : 250 means that one inch on the map is equal to 250 inches on the ground.

VNC. A visual flight rules (VFR) navigation chart (VNC) is a chart used primarily for visual navigation, at low altitudes (below 18 000 feet) and slower speeds (less than 300 knots). A VNC has a scale of 1 : 500 000, or one inch to eight miles.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. What is a graticule?

Q2. How many nautical miles are in one minute of latitude?

Q3. How many feet are in a statute mile?

ANTICIPATED ANSWERS

A1. A three-dimensional geometrical pattern of intersecting circles.

A2. One.

A3. 5 280 feet.

Teaching Point 2	Identify and Describe Types of Navigation
Time: 5 min	Method: Interactive Lecture

TYPES OF NAVIGATION

There are several methods of navigation used by pilots to find their way from place to place. Four of the more common methods used include:

- pilotage,
- dead reckoning,
- inertial navigation, and
- satellite navigation.

Pilotage. This method of navigation is by reference to landmarks only. This is similar to orienteering.

Dead Reckoning. This method of navigation uses predetermined vectors of wind and true airspeed, precalculated heading and groundspeed, and estimated time of arrival. This is the most common method used by private pilots.

Inertial Navigation. This method of navigation is through use of gyroscopic equipment and electronic computers to provide a continuous display of position. This equipment is built into the aircraft.

Satellite Navigation. This method uses position and guidance systems, which transmit to and receive information from orbiting satellites. The global positioning system (GPS) is the most commonly used satellite system with many new aircraft having complex units built into the instrument panel.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. What is pilotage?

Q2. Which is the most common navigation method used by private pilots?

Q3. What is the most commonly used satellite navigation system?

ANTICIPATED ANSWERS

A1. This method is navigation by reference to landmarks only.

A2. Dead reckoning.

A3. GPS.

Teaching Point 3	**Demonstrate and Have the Cadet Determine the Distance Between Two Predetermined Points Along a Route**
Time: 15 min	Method: Demonstration and Performance

MEASURING DISTANCE

International Civil Aviation Organization (ICAO) Ruler

The ICAO ruler is a simple straight edge with four measuring scales embossed into it. The scale used depends on the type of map and unit of measurement desired. For a VNC, the scale would be 1 : 500 000. Since all distances in aviation are given in nm, this is the measurement used when determining distance.

Place the ruler on the map, with the starting point at zero. Be sure to use the 1 : 500 000 side and the nm scale. Adjust the ruler so that the destination point is on the same edge as the start point, and measure across. The value found on the nm scale is the distance between the two points.

Map Scale

The distance can also be measured using the map scale. On the reverse side of the map legend there is a graduated scale for that map. It will show nm, statute miles, and km. Take a piece of paper and line it up on the map between the two points. Use a pencil to mark where the two points are on the paper. Line the paper up with the graduated scale, on the nm line, and determine the distance. If the distance on the map is greater than the graduated scale, simply mark off the end of the graduated scale on the paper, shift the paper down so that the new mark is set to zero and remeasure. Depending on the length of the route, some basic math may be required as the paper may have to be readjusted.

Remember that the distance between minutes of latitude is one nm. This means that if two points are directly north or south of each other, count up the number of minutes of latitude between them and this equals the distance.

ACTIVITY

OBJECTIVE

The objective of this activity is to determine the distance between two points along a route.

RESOURCES

- ICAO ruler,
- VNC,
- Pencil, and
- Eraser.

ACTIVITY LAYOUT

Desks are to be arranged so that cadets can work in pairs.

ACTIVITY INSTRUCTIONS

1. Distribute one VNC to each pair of cadets.

2. Distribute one ICAO ruler to each pair of cadets.
3. Using two predetermined points, demonstrate to the cadets how to use the ICAO ruler.
4. Provide the cadets with a second set of predetermined points.
5. Have the cadets measure the distance between these two points using the ICAO ruler.
6. Provide the cadets with two more sets of points and allow them to practice.
7. If time permits, demonstrate to the cadets how to measure the distance using the scale of the map.
8. Have the cadets use the scale of the map to determine the distances of the previously used sets of points. Confirm with the results of the ICAO ruler.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 3

The cadets' participation in the measuring activity will serve as confirmation of this TP

END OF LESSON CONFIRMATION

The cadets' participation in the activity in TP 3 will serve as confirmation of this EO.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

This EO is assessed IAW Chapter 3, Annex B, Aviation Subjects – Combined Assessment PC.

CLOSING STATEMENT

Measuring a distance along a route is very useful in aviation as well as other methods of travel. Being aware of scale and knowing how to use that information will ensure efficient trip planning.

INSTRUCTOR NOTES/REMARKS

VNCs and ICAO rulers can be ordered through the Area Cadet Officer (ACO), purchased at a local flight training centre, or ordered online at NavCanada (www.navcanada.ca).

EO C337.02 (Practice Air Navigation Skills, Section 4) may be conducted to provide extra practice of the skills learned in this EO.

REFERENCES

C3-116 (ISBN 0-9680390-5-7) MacDonald, A. F., & Peppler, I. L. (2000). *From the Ground Up: Millennium Edition*. Ottawa, ON: Aviation Publishers Co. Limited.

C3-139 (ISBN 0-7715511-5-0) Transport Canada. (1999). *Flight Training Manual: 4th Edition Revised*. Ottawa, ON: Transport Canada.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 2

EO M337.02 – DETERMINE A POSITION ON A VISUAL FLIGHT RULES (VFR) NAVIGATIONAL CHART (VNC)

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create a list of predetermined coordinates that correspond to airports on the VNC to be used in TP 3.

Create a list of locations to be used in TP 4.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for TPs 1 and 2 to introduce basic air navigation terms.

Demonstration and performance was chosen for TPs 3 and 4 as it allows the instructor to explain and demonstrate determining positions and coordinates while providing an opportunity for the cadet to practice under supervision.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have determined a position on a VNC.

IMPORTANCE

It is important for cadets to be able to determine a position on a VNC as this is a transferable skill in any type of navigation which uses maps that have a graticule.

Teaching Point 1 | **Explain that the Earth is Divided Into Sections by an Imaginary Grid System Called a Graticule**

Time: 5 min | Method: Interactive Lecture

GRATICULE

A graticule is a three-dimensional geometrical pattern of intersecting circles. Envision the black lines on a basketball, or a globe with only the black lines. When applied to the earth, either on a globe or a map, we refer to these intersecting lines as parallels of latitude and meridians of longitude.

Parallels of Latitude

Parallels of latitude are a series of concentric circles, which measure north and south. The baseline for measuring is the equator, which is 0 degrees of latitude. As one travels away from the equator the degree of latitude becomes larger, to a maximum of 90 degrees north or south. The southern borders of Canada's Prairie Provinces lie on the 49th parallel of latitude, and are therefore at 49 degrees north latitude. Latitude is expressed in degrees (°), minutes ('), and seconds ("). Though the terms are similar, latitude is not a measurement of time and is actually related to distance. One minute of latitude is equal to one nautical mile (nm).

Meridians of Longitude

Meridians of longitude are a series of circles, which measure east and west. The baseline for measuring is the prime meridian, which runs north to south through Greenwich, England. The prime meridian is 0 degrees of longitude. As one travels away from the prime meridian the degree of longitude becomes larger, to a maximum of 180 degrees east or west. Many meridians of longitude pass through Canada, with one being made famous by the Tragically Hip song "Hundredth Meridian". Longitude is expressed in degrees (°), minutes ('), and seconds ("). Longitude is not a measurement of time, but there is a relationship between time and longitude.

The Equator

The equator is the only parallel of latitude, which divides the earth into two equal halves. It is expressed as 0 degrees of latitude and is the dividing line between the northern and southern hemispheres.

The Prime Meridian

The prime meridian is one half of a circle, which will divide the earth into two equal halves. The other half is the International Date Line. The prime meridian is expressed as 0 degrees of longitude, while the International Date Line is expressed as 180 degrees of longitude. Both lines divide the earth into the western and eastern hemispheres.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. What is a graticule?

Q2. Which directions do parallels of latitude measure?

Q3. Which directions do meridians of longitude measure?

ANTICIPATED ANSWERS

A1. A graticule is a three-dimensional geometrical pattern of intersecting circles.

A2. Parallels of latitude measure north and south from the equator.

A3. Meridians of longitude measure east and west from the prime meridian.

Teaching Point 2	**Explain Geographical Coordinates**
Time: 5 min	Method: Interactive Lecture

GEOGRAPHICAL COORDINATES

The locations of cities, towns, and airports may be designated by their geographical coordinates. These coordinates express where a parallel of latitude intersects with a meridian of longitude. This is similar in principle to the X-and Y-axis on a graph.

Units of Measurement

Both latitude and longitude use the same units of measurement: degrees, minutes, and seconds. There are 60 seconds in a minute and 60 minutes in a degree. For latitude, this means that one degree is equal to 60 nm.

Sequencing

When expressing geographical coordinates, latitude is always shown first and longitude second. Whenever possible, coordinates should be given in the greatest detail. This means using degrees, minutes and seconds of latitude and longitude. The more precise the coordinates, the easier it will be to find a location.

Examples of coordinates include:

- Penticton Airport: N 49° 27' 47" W 119° 36' 08"
- Red Deer Airport: N 52° 10' 43" W 113° 53' 35"
- St. Jean Airport: N 45° 17' 40" W 73° 16' 52"
- Debert Airport: N 45° 25' 07" W 63° 27' 28"

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. What are geographical coordinates used for?

Q2. How are geographical coordinates expressed?

Q3. What is an example of a coordinate?

ANTICIPATED ANSWERS

A1. Designating the location of cities, towns, and airports.

A2. Latitude is always shown first, longitude second.

A3. Answers may vary. Use examples in TP 2 as a guide.

Teaching Point 3	Given a Set of Coordinates, Demonstrate and Have the Cadet Determine the Location of an Airport
Time: 10 min	Method: Demonstration and Performance

ACTIVITY

OBJECTIVE

The objective of this activity is to determine the location of an airport using coordinates.

RESOURCES

- Paper,
- Tape or adhesive putty,
- VNC, and
- Predetermined sets of coordinates for airports.

ACTIVITY LAYOUT

Arrange the classroom so that each pair may work with a VNC.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into pairs.
2. Write three sets of coordinates on the whiteboard and cover them with paper.
3. Distribute one VNC to each pair of cadets.
4. Uncover the first set of coordinates, and demonstrate how to find the airport.
5. Have the cadets find the airport at those coordinates. Assist as necessary.
6. Uncover the second set of coordinates and repeat step five.
7. Uncover the third set of coordinates and repeat step five.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 3

The cadets’ participation in the locating an airport activity will serve as confirmation of this TP.

Teaching Point 4 — **Demonstrate and Have the Cadet Determine the Coordinates of a Given Location on a Map**

Time: 5 min — Method: Demonstration and Performance

ACTIVITY

OBJECTIVE

The objective of this activity is to determine the coordinates of a given location on a map.

RESOURCES

- Paper,
- Tape or adhesive putty,
- VNC, and
- Predetermined locations on a map.

ACTIVITY LAYOUT

Arrange the classroom so that each pair may work with a VNC.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into pairs.
2. Write two locations on the whiteboard and cover with paper.
3. Distribute one VNC to each pair of cadets.
4. Choose a location on the map and demonstrate how to determine the coordinates.
5. Uncover the first location. Assist cadets by giving them general directions (eg, trace a line with their fingers northeast of city X).
6. Have the cadets determine the coordinates of that location. Assist as necessary.
7. Uncover the second set of coordinates and repeat step five and six.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 4

The cadets' participation in the determining coordinates activity will serve as confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' participation in the activities in TPs 3 and 4 will serve as confirmation of this lesson.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

This EO is assessed IAW Chapter 3, Annex B, Aviation Subjects – Combined Assessment PC.

CLOSING STATEMENT

Determining a location on a map is a very useful skill that cadets may use throughout life, not just in aviation. This skill can transfer to survival, outdoor sports, or travel of any kind.

INSTRUCTOR NOTES/REMARKS

VNCs can be ordered through your Area Cadet Officer (ACO), purchased at a local flight training centre, or ordered online at NavCanada.

EO C337.02 (Practice Air Navigation Skills, Section 4) may be conducted to provide extra practice of the skills learned in this EO.

REFERENCES

C3-116 (ISBN 0-9680390-5-7) MacDonald, A. F., & Peppler, I. L. (2000). *From the Ground Up: Millennium Edition*. Ottawa, ON: Aviation Publishers Co. Limited.

C3-139 (ISBN 0-7715511-5-0) Transport Canada. (1999). *Flight Training Manual: 4th Edition Revised*. Ottawa, ON: Transport Canada.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 3

EO C337.01 – OPERATE A RADIO FOR AVIATION TRANSMISSION

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create several scripts using the examples located at Annex B as a guide.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An in-class activity was chosen for TP 1 as an interactive way to review the phonetic alphabet.

Demonstration and performance was chosen for TPs 2 and 3 as it allows the instructor to explain and demonstrate operating a radio while providing an opportunity for the cadet to practice radio transmissions under supervision.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have operated a radio for aviation transmissions.

IMPORTANCE

It is important for cadets to be able to operate a radio for aviation transmissions as it will improve their verbal communication skills and add to their comprehension and enjoyment of familiarization flights.

Teaching Point 1 **Review the Phonetic Alphabet and Numbers**

Time: 5 min Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is to review the phonetic alphabet and numbers.

RESOURCES

N/A.

ACTIVITY LAYOUT

N/A.

ACTIVITY INSTRUCTIONS

1. Write the phonetic alphabet and numbers on the whiteboard or flip chart.
2. Have each cadet spell out their first and last name using the phonetic alphabet.
3. Have each cadet count from 1 to 5 or from 5 to 10 using the phonetic numbers.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 1

The cadets' participation in the phonetics activity will serve as confirmation of TP 1.

Teaching Point 2 **Explain, Demonstrate and Have the Cadet Practice Operating a Radio to Communicate the Arrival of an Aircraft**

Time: 10 min Method: Demonstration and Performance

Arrival messages are transmitted in order to communicate intentions, clearances and instructions. An airport can be a busy place, with many aircraft arriving and departing in short spans of time. This can cause confusion if proper communication is not practiced.

There are normally four parts to a radio message, including:

1. the call-up,
2. the reply,
3. the message, and
4. the acknowledgement or ending.

All parts of the message should be clear, concise and in phonetics where appropriate.

ACTIVITY

Time: 5 min

OBJECTIVE

The objective of this activity is to demonstrate and have the cadet perform operating a radio to communicate the arrival of an aircraft.

RESOURCES

- Hand-held radio, and
- Script of phrases.

ACTIVITY LAYOUT

Arrange the classroom to facilitate small group work over a short distance.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into pairs.
2. Distribute one radio and a script located at Annex B, page 14B-1 to each cadet.
3. Demonstrate the four parts of a radio message that communicate the arrival of an aircraft.
4. Have the cadets practice operating a radio to communicate the arrival of an aircraft.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 2

The cadets' participation in the radio activity for communicating the arrival of an aircraft activity will serve as the confirmation of this TP.

Teaching Point 3	**Explain, Demonstrate and Have the Cadet Practice Operating a Radio to Communicate the Departure of an Aircraft**
Time: 10 min	Method: Demonstration and Performance

Departure messages are transmitted in order to communicate intentions, clearances and instructions.

All parts of the message should be clear, concise and in phonetics where appropriate.

ACTIVITY

Time: 5 min

OBJECTIVE

The objective of this activity is to demonstrate and have the cadet perform operating a radio to communicate the departure of an aircraft.

RESOURCES

- Hand-held radio, and
- Script of phrases.

ACTIVITY LAYOUT

Arrange the classroom to facilitate small group work over a small distance.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into pairs.
2. Distribute one radio and a script located at Annex B, page 14B-2 to each cadet.
3. Demonstrate the four parts of a radio message that communicate the departure of an aircraft.
4. Have the cadets practice operating a radio to communicate the departure of an aircraft.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 3

The cadets' participation in the operation of a radio for communicating the departure of an aircraft activity will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' participation in the operation of a radio for aviation transmission activities will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Proper communication over the radio is essential. Some messages may contain a large amount of information that must be transmitted in a brief message. This skill will assist in developing effective verbal communication while using a radio.

INSTRUCTOR NOTES/REMARKS

Depending on available resources, this EO may be conducted on the familiarization flying day in cooperation with the Technical Training Establishment (TTE).

REFERENCES

C3-116 (ISBN 0-9680390-5-7) MacDonald, A. F., & Peppler, I. L. (2000). *From the Ground Up: Millennium Edition*. Ottawa, ON: Aviation Publishers Co. Limited.

C3-182 *Study Guide for the Radiotelephone Operator's Restricted Certificate (Aeronautical)*. (1990). Retrieved October 23, 2007, from http://www.ic.gc.ca/epic/site/smt-gst.nsf/en/sf01397e.html.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 4

EO C337.02 – PRACTICE AIR NAVIGATION SKILLS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Develop a list of points and coordinates for airports to be used in TP 1.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

A practical activity was chosen for this lesson so that the cadets may further develop skills learned in EO M337.01 (Measure Distance Along a Route, Section 1) and EO M337.02 (Determine a Position on a Visual Flight Rules [VFR] Navigational Chart [VNC], Section 2).

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have practiced air navigation skills.

IMPORTANCE

It is important for cadets to practice air navigation skills as each cadet may find an opportunity to use these skills in any trip planning, whether aviation based or not.

Teaching Point 1 **Practice Air Navigation Skills**

Time: 25 min Method: Practical Activity

The following activities are designed to be conducted concurrently. Some cadets may need to practice measuring distance along a route, while others may need to practice determining position on a Visual Flight Rules (VFR) Navigation Chart (VNC). Determine which cadets need practice with which skill, and then divide the cadets accordingly. Cadets working on different activities may share the same map to lessen the strain on resources.

ACTIVITY

OBJECTIVE

The objective of this activity is to practice measuring distance along a route.

RESOURCES

- Predetermined points,
- VNC,
- International Civil Aviation Organization (ICAO) Ruler,
- Pencil, and
- Eraser.

ACTIVITY LAYOUT

The classroom should be arranged to facilitate individual and group work, depending on the skill level of each cadet.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into pairs based on the activity that they will participate in. Two cadets working on different activities may be paired up to use the same map if needed.
2. Distribute one VNC and one ICAO ruler to each pair of cadets.
3. Using two predetermined points, demonstrate to the cadets how to use the ICAO ruler.
4. Provide the cadets with a second set of predetermined points.
5. Have the cadets measure the distance between these two points using the ICAO ruler.
6. Provide the cadets with two more sets of points and allow them to practice.
7. If time permits, demonstrate to the cadets how to measure the distance using the scale of the map.
8. Have the cadets use the scale of the map to determine the distances of the previously used sets of points. Cross-check with the results of the ICAO ruler.

SAFETY

N/A.

ACTIVITY

OBJECTIVE

The objective of this activity is to practice determining position on a VNC.

RESOURCES

- Paper,
- Tape or adhesive putty,
- VNC, and
- Predetermined sets of coordinates for airports.

ACTIVITY LAYOUT

The classroom should be arranged to facilitate individual and group work, depending on the skill level of each cadet.

ACTIVITY INSTRUCTIONS

1. Write three sets of coordinates on the whiteboard and cover with paper.
2. Divide the cadets into pairs based on the activity that they will participate in. Two cadets working on different activities may be paired up to use the same map if needed.
3. Distribute one VNC to each pair of cadets. Cadets who wish to work independently may still share a map.
4. Uncover the first set of coordinates.
5. Have the cadets find the airport at those coordinates. Assist as necessary.
6. Uncover the second set of coordinates and repeat step four.
7. Uncover the third set of coordinates and repeat step four.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 1

The cadets' participation in the activities in TP 1 will serve as confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' practicing measuring distance along a route and determining position on a VNC will serve as confirmation of this lesson.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Measuring distance and determining position on a map are transferable skills to any other method of travel.

INSTRUCTOR NOTES/REMARKS

This EO is designed to complement EO M337.01 (Measure Distance Along a Route, Section 1) and EO M337.02 (Determine a Position on a Visual Flight Rules [VFR] Navigational Chart [VNC], Section 2) as extra time to practice the skills.

REFERENCES

N/A.

AIR NAVIGATION TERMS

Graticule. A three-dimensional geometrical pattern of intersecting circles. Envision the black lines on a basketball, or a globe with only the black lines.

Latitude. Parallels of latitude are imaginary circles on the earth's surface, which lie parallel to the equator. Latitude measures 90 degrees north and 90 degrees south of the equator. Parallels of latitude make up half of the earth's graticule. Latitude is measured in degrees (°), minutes ('), and seconds (").

Longitude. Meridians of longitude are imaginary circles on the earth's surface, which intersect at the true or geographic poles, and join the poles of the earth together. Longitude measures 180 degrees west and 180 degrees east of the prime meridian (0 degrees), which passes through Greenwich, England. Meridians of longitude make up the other half of the earth's graticule. Longitude is measured in degrees (°), minutes ('), and seconds (").

Nautical Miles. A nautical mile (nm) is 6 080 feet and is the average length of one minute of latitude.

Statute Miles. A statute mile is 5 280 feet.

Scale. Scale on a map is the relationship between a unit of distance on the chart to the distance on the earth that the unit represents. For example, a scale of 1 : 250 means that one inch on the map is equal to 250 inches on the ground.

VNC. A visual flight rules (VFR) navigation chart (VNC) is a chart used primarily for visual navigation, at low altitudes (below 18 000 feet) and slower speeds (less than 300 knots). A VNC has a scale of 1 : 500 000, or one inch to eight miles.

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EXAMPLES OF ARRIVAL AND DEPARTURE COMMUNICATIONS

Arrival

1.	The call-up:	Schefferville Radio This is Piper Foxtrot Alfa Bravo Charlie Over
2.	The reply:	Piper Foxtrot Alfa Bravo Charlie This is Schefferville Radio Go ahead Over
3.	The message:	Schefferville Radio This is Piper Foxtrot Alfa Bravo Charlie Four miles at one thousand Landing Schefferville Over
		Piper Foxtrot Alfa Bravo Charlie This is Schefferville Radio Roger Wind – one six zero at one five Altimeter – two niner niner seven Over
4.	The acknowledgement:	Schefferville Radio This is Piper Foxtrot Alfa Bravo Charlie Roger

Departure

1.	The call-up:	Schefferville Radio This is Piper Foxtrot Alfa Bravo Charlie Over
2.	The reply:	Piper Foxtrot Alfa Bravo Charlie This is Schefferville Radio Go ahead Over
3.	The message:	Schefferville Radio This is Piper Foxtrot Alfa Bravo Charlie Holding short of runway Tree Tree on Alfa Ready for takeoff Over
		Piper Foxtrot Alfa Bravo Charlie This is Schefferville Radio Proceed at your discretion Wind – three two zero at one zero Over
4.	The acknowledgement:	Schefferville Radio Piper Foxtrot Alfa Bravo Charlie Roger

CHAPTER 15

PO 340 – IDENTIFY ASPECTS OF SPACE EXPLORATION

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 1

EO M340.01 – IDENTIFY CANADIAN ASTRONAUTS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Choose two astronauts to be the focus of this lesson.

Retrieve current information about the chosen astronauts from the annexes and update with information from the reference.

Create a slide of each astronaut's photograph.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to orient the cadets to Canadian astronauts, to generate interest in Canada's space program, and to emphasize the teaching points.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have identified Canadian astronauts.

IMPORTANCE

It is important for cadets to identify Canadian astronauts so that they can become familiar with the Canadian space program. The hard work that astronauts perform will illustrate the Air Force motto: Per Ardua ad Astra, as well as the rewards that can be achieved by men and women who accept the challenge of the stars.

Teaching Point 1 | **Identify Canadian Astronauts**

Time: 10 min | Method: Interactive Lecture

Training of Canada's astronauts began in 1983 and Canada's first astronaut, Marc Garneau, visited space in October 1984, when, among many other mission accomplishments, the Canada Experiment (CANEX) payload performed important experiments. Those early CANEX experiments were:

- Auroral Photography Experiment (APE),
- Radiation Monitoring Equipment (RME), and
- Thermoluminiscent Dosimeter (TLD).

Since that time both the astronaut cadre and Canada's space program have grown. Some astronauts have retired after brilliant careers and new members have joined the team. Some of Canada's astronauts include:

- Marc Garneau (Canada's first astronaut),
- Roberta Bondar (Canada's first woman astronaut),
- Steve MacLean,
- Chris Hadfield,
- Robert Thirsk,
- Bjarni Tryggvason,
- David Williams, and
- Julie Payette.

Show the cadets the slides of photographs located at Annexes A to H.

Using information retrieved from the reference, identify the Canadian astronaut who most recently made his or her first space journey.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. In what year did training of Canada's astronauts begin?

Q2. When did Canada's first astronaut visit space?

Q3. Who was Canada's first astronaut?

ANTICIPATED ANSWERS

A1. 1983.

A2. October 1984.

A3. Marc Garneau.

Teaching Point 2 | **Discuss the Professional and Personal Profiles of Two Canadian Astronauts**

Time: 15 min | Method: Interactive Lecture

Discuss the following information about the two chosen astronauts, using information located at the respective annexes or retrieved from the reference, to include:

a. missions undertaken,

b. place and date of birth,

c. education,

d. professional experience,

e. special honours, and

f. affiliations.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. In what missions did these astronauts take part?

Q2. What part did these astronauts play on these missions?

Q3. What education and experience did these astronauts bring to the missions?

ANTICIPATED ANSWERS

A1. As per lesson content in TP 2.

A2. As per lesson content in TP 2.

A3. As per lesson content in TP 2.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. Which Canadian astronaut most recently made his or her first space journey?

Q2. Who was Canada's first astronaut?

Q3. Who was Canada's first woman astronaut?

ANTICIPATED ANSWERS

A1. As per lesson content in TP 1.

A2. Marc Garneau.

A3. Roberta Bondar.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Space missions have a short history and a vast future. Cadets can stay current with the space program by frequently visiting websites of the Canadian Space Agency (CSA), the US National Aeronautics and Space Administration (NASA) and websites of other organizations such as the European Space Agency (ESA).

INSTRUCTOR NOTES/REMARKS

The instructor shall obtain the latest biographical information for this EO. This material must be updated each year to reflect the Canadian Space Agency's recent activities.

A list shall be kept of astronauts that cadets have focused on to prevent repetition, since other lessons, such as EO C340.01 (Identify Canadian Astronauts, Section 3), may introduce other astronauts in the future.

REFERENCES

C3-238 Canadian Space Agency. (2008). *Canadian Space Agency*. Retrieved February 9, 2008, from http://www.space.gc.ca/asc/eng/default.asp.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 2

EO M340.02 – DISCUSS THE HISTORY OF MANNED SPACE EXPLORATION

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of figures located at Annexes I to L.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to orient the cadets, generate interest, present background material, and clarify the history of manned space exploration.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have discussed the history of manned space exploration.

IMPORTANCE

It is important for cadets to learn about the history of manned space exploration because in the near future, space exploration will become increasingly significant as developing technologies and resource depletion move humanity's focus beyond earth.

Teaching Point 1 | **Discuss the Mercury Program**

Time: 5 min | Method: Interactive Lecture

Show the cadets the early manned space exploration timeline located at Annex I.

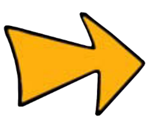
On May 5, 1961, America's first astronaut, Alan Shepard, blasted into space on a Redstone rocket. His history-making suborbital flight was in a one-man capsule named Freedom 7, which was only two metres long and less than two metres in diameter.

Show the cadets Figure 15I-1.

OBJECTIVES OF THE MERCURY PROGRAM

Specific studies and tests conducted by the US government and industry, culminating in 1958, indicated the feasibility of manned space flight. The objectives of the Mercury program, as stated at the time of project commencement in November 1958, were:

- place a manned spacecraft in orbital flight around the earth;
- investigate man's performance capabilities and his ability to function in the environment of space; and
- recover the man and the spacecraft safely.



The 1983 movie *The Right Stuff* is based on the story of the Mercury program.

HISTORY OF THE MERCURY PROGRAM

The US' first manned space flight project was successfully accomplished in less than five years, which saw more than 2 000 000 people from major government agencies and the aerospace industry combine their skills, initiative and experience into a national effort.

In this period, six manned space flights were accomplished as part of a 25-flight program. These manned space flights were accomplished with complete pilot safety and without change to the basic Mercury objectives.

It was shown that man could function ably as a pilot-engineer-experimenter without undesirable reactions or deteriorations of normal body functions for periods up to 34 hours of weightless flight. Directing this large and fast moving project required the development of a management structure and operating mode that satisfied the requirement to mould the many different entities into a workable structure.

Timeline of the Mercury Program

- October 1, 1958 National Aeronautics and Space Administration (NASA) created

- November 26, 1958 Mercury program announced
- December 4, 1959 Launch of Sam (a monkey) on Little Joe 2
- April 9, 1959 NASA names the seven Mercury astronauts
- January 21, 1960 Launch of Miss Sam (a monkey) on Little Joe IB
- January 31, 1961 Launch of Ham (a chimpanzee) on Mercury Redstone 2
- May 5, 1961 Launch of Alan Shepard in Freedom 7 (suborbital)
- July 21, 1961 Launch of Gus Grissom in Liberty 7 (suborbital)
- November 29, 1961 Launch of Enos (a chimpanzee) on Mercury Atlas 5 (orbital)
- January 3, 1962 Gemini program formally conceived
- February 20, 1962 Launch of John Glenn in Friendship 7, first American human orbital flight
- May 24, 1962 Launch of Scott Carpenter in Aurora 7
- October 3, 1962 Launch of Walter Schirra in Sigma 7
- May 15, 1963 Launch of Gordon Cooper in Faith 7, the final mission of the Mercury program

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. Who was America's first astronaut to go into space?

Q2. Which movie portrays the Mercury program?

Q3. How many manned missions were there in the Mercury program?

ANTICIPATED ANSWERS

A1. Alan Shepard.

A2. *The Right Stuff*.

A3. Six.

Teaching Point 2	**Discuss the Gemini Program**
Time: 5 min	Method: Interactive Lecture

Show the cadets the early manned space exploration timeline located at Annex I.

OBJECTIVES OF THE GEMINI PROGRAM

The Gemini program was a necessary intermediate step between the Mercury program and the Apollo program. It had four objectives:

- to subject astronauts to long duration flights – a requirement for projected later trips to the moon or deeper space;

- to develop effective methods for rendezvous and docking with other orbiting vehicles and to manoeuvre the docked vehicles in space;
- to perfect methods of re-entry and landing spacecraft at a pre-selected ground landing point; and
- to gain additional information concerning the effects of weightlessness on crew members and to record the physiological reactions of crew members during longer duration flights.

HISTORY OF THE GEMINI PROGRAM

On May 25, 1961, three weeks after Mercury astronaut Alan Shepard became the first American in space, President John F. Kennedy announced the goal to send astronauts to the moon before the end of the decade. To facilitate this goal, NASA expanded the existing manned space flight program in December 1961 to include the development of a two-man spacecraft. The program was officially designated Gemini on January 3, 1962.

Gemini, to a large degree, was the work of a Canadian – James Arthur Chamberlin of Kamloops, British Columbia, a mechanical engineer educated at the University of Toronto. Having served as the chief engineer for the Mercury program, Chamberlin was selected to be Gemini's Project Manager.

Show the cadets Figure 15J-1.

Gemini was named after the third constellation of the Zodiac and its twin stars, Castor and Pollux, because of its two-man crew.

Show the cadets Figure 15J-2.

Gemini consisted of 12 flights, including two unmanned flight tests of the equipment:

- March 23, 1965 — Gemini III – First manned Gemini flight completed three orbits
- June 03–07, 1965 — Gemini IV – First American Extravehicular Activity (EVA)
- August 21–29, 1965 — Gemini V – First use of fuel cells for electrical power
- December 04–18, 1965 — Gemini VII – First rendezvous in space, with Gemini VI-A
- December 15–16, 1965 — Gemini VI-A – First rendezvous in space, with Gemini VII

Show the cadets Figure 15J-3.

- March 16, 1966 — Gemini VIII – First docking with another (unmanned) spacecraft by astronauts Neil Armstrong and David Scott
- June 03–06, 1966 — Gemini IX-A – Three rendezvous and two hours of EVA
- July 18–21, 1966 — Gemini X – Rendezvoused with target vehicle and EVA
- September 12–15, 1966 — Gemini XI – Gemini record altitude of 1 189.3 km
- November 11–15, 1966 — Gemini XII – Final Gemini flight: rendezvous, docking, EVA

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. Who was the Gemini Project Manager?

Q2. How many astronauts were on a Gemini flight?

Q3. Which astronauts accomplished the first docking with another space vehicle?

ANTICIPATED ANSWERS

A1. James Arthur Chamberlin of Kamloops, British Columbia.

A2. Two.

A3. The Gemini crew of Neil Armstrong and David Scott.

Teaching Point 3	**Discuss the Apollo Program**
Time: 5 min	Method: Interactive Lecture

Show the cadets the early manned space exploration timeline located at Annex I.

July 20, 1969: "Houston, Tranquility Base here. The Eagle has landed." were the famous first words spoken from the moon.

OBJECTIVES OF THE APOLLO PROGRAM

The Apollo's program objectives went beyond landing Americans on the moon and returning them safely to earth. The objectives also included:

- establishing the technology to meet other national interests in space;
- achieving pre-eminence in space for the United States;
- carrying out a program of scientific exploration of the moon; and
- developing man's capability to work in the lunar environment.

HISTORY OF THE APOLLO PROGRAM

The Apollo program was the work of Owen E. Maynard of Sarnia, Ontario, chief of the systems engineering division in the Apollo Spacecraft Program Office. He was previously chief of the Lunar Module engineering office in the Apollo Program Office at the Manned Spacecraft Center in Houston. Maynard held an aeronautical engineering degree from the University of Toronto. His years at NASA were rewarded on July 20, 1969, when Apollo 11 commander Neil Armstrong stepped out of the lunar module (LM) and took one small step in the Sea of Tranquility, calling it a giant leap for mankind. Maynard remained in charge of Apollo systems engineering until he left NASA in 1970 following the successful achievement of Kennedy's lunar landing goal. Thereafter he returned to private industry.

Show the cadets Figure 15K-1.

The Apollo program used the Saturn family of launch vehicles. The command, service and lunar module made a small package, dwarfed at the top of the giant launch vehicle.

Show the cadets Figure 15K-2.

The command module (CM) was small for three men to spend 8 days, 3 hours and 18 minutes in it. On the *Apollo 11* journey of July, 1969, the three men were Neil Armstrong (commander), Michael Collins (CM pilot) and Edwin (Buzz) Aldrin Jr. (LM pilot).

Show the cadets Figure 15K-3.

Six of the Apollo missions, *Apollos 11, 12, and 14–17*, landed on the moon, studying soil mechanics, meteoroids, seismic activity, heat flow, lunar ranging, magnetic fields and solar wind.

Apollos 7 and 9 tested spacecraft in earth orbit; *Apollo 10* orbited the moon as the dress rehearsal for the first landing. An oxygen tank explosion forced *Apollo 13* to scrub its landing, but the can-do problem-solving of the crew and mission control – and Maynard's systems engineering group – turned the mission into what was called a successful failure.

The 1995 movie *Apollo 13* is based on the story of the 1970 mission to the moon.

Apollo Flight Summary

- October 1968 *Apollo 7* – Earth orbit
- December 1968 *Apollo 8* – Ten lunar orbits

- March 1969 *Apollo 9* – First manned flight of lunar module
- May 1969 *Apollo 10* – Dress rehearsal for Moon landing
- July 20 1969 *Apollo 11* – First lunar landing mission (on the Sea of Tranquility)
- November 1969 *Apollo 12* – Second lunar landing (on the Ocean of Storms)
- April 1970 *Apollo 13* – Mission aborted after an on-board explosion
- January 1971 *Apollo 14* – Third lunar landing (at Fra Mauro)
- July 1971 *Apollo 15* – Fourth lunar landing (in the Hadley Apennine region)
- April 1972 *Apollo 16* – Fifth lunar landing (on the Descartes highlands)
- December 1972 *Apollo 17* – Last lunar landing (on the Taurus Littrow highlands)

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. Which family of launch vehicles were used for Project Apollo?

Q2. Who was chief of systems engineering for the Apollo Project?

Q3. What was the date of Apollo's first manned moon landing?

ANTICIPATED ANSWERS

A1. The Saturn family.

A2. Owen E. Maynard of Sarnia, Ontario.

A3. July 20, 1969.

Teaching Point 4 **Discuss the Russian Manned Space Program**

Time: 10 min Method: Interactive Lecture

The Mir space station, which was shared by Russian cosmonauts and American astronauts, was a continuation of the Soviet space program. Construction of Mir began in 1986, before the Soviet Union was disbanded. Mir was preceded by many years of Soviet space development which included, among many other programs, the Vostok missions, the Soyuz missions and the Salyut space station.

VOSTOK

The Vostok program (Восто́к, translated as "East") was a Soviet human spaceflight project that succeeded in putting a person into earth's orbit for the first time.

Show the cadets Figure 15L-1.

Vostok manned record-breaking flights included:

- April 12, 1961 *Vostok-1* – First man in space (Yuri Gagarin)

- August 6, 1961 *Vostok-2* – First full day in space
- August 11, 1962 *Vostok-3* – First of two simultaneous manned spacecraft
- August 12, 1962 *Vostok-4* – Second of two simultaneous manned spacecraft
- June 14, 1963 *Vostok-5* – Longest solo orbital flight
- June 16, 1963 *Vostok-6* – First woman in space (Valentina Tereshkova)

SOYUZ

The Soyuz program (meaning "Union") is a human spaceflight program that was initiated by the Soviet Union in the early 1960s. It was originally part of a moon landing program intended to put a Soviet cosmonaut on the moon. Both the Soyuz spacecraft and the Soyuz launch vehicle were part of this program, which later became the responsibility of the Russian Federal Space Agency.

The Soyuz program produced many experimental variants, but its development is commonly divided into three historical parts:

- Early era: *Soyuz-1 to Soyuz-9* (1966–1970),
- Salyut era: *Soyuz-10 to Soyuz T-14* (1971–1985), and
- Mir era: *Soyuz T-15 to Soyuz TM-30* (1986–2000).

Unlike the one-man Vostok spacecraft, the first three-seat Soyuz was able to conduct active manoeuvring, orbital rendezvous and docking. These features would all have been necessary for a flight around the moon or for a lunar expedition. In the early plans for circumlunar flight, the Soyuz was to be a three-part spacecraft assembled in the low-earth orbit from parts delivered by separate launch vehicles. This plan was later abandoned in favour of a two-launch and, later, a single-launch method.

In 1971, a three-seat Soyuz delivered two crews to the first Salyut space station. Disaster struck when the first Salyut crew returned from orbit. The sudden depressurization of the re-entry capsule killed all three cosmonauts. As a result of this tragedy, the designers introduced protective pressure suits, but at the expense of room for one crewmember. Two-seat Soyuz spacecraft then continued ferrying the crews to the Salyut and Almaz space stations.

SALYUT AND MIR SPACE STATIONS

First-Generation Salyut Stations (1964–1977)

First-generation Salyut space stations had one docking port and could not be resupplied or refuelled. The stations were launched unmanned and later occupied by crews. There were two types: Almaz military stations and Salyut civilian stations. To Western observers, both types were Salyut stations, including:

- 1971 *Salyut-1* – First space station (civilian)
- 1973 *Salyut-2* – First Almaz station (military, failure)
- 1974–75 *Salyut-3* – Almaz station (military)
- 1974–77 *Salyut-4* – Civilian space station
- 1976–77 *Salyut-5* – Last Almaz station (military)

Show the cadets Figures 15L-2 and 15L-3.

Second-Generation Stations (1977–1985)

Second-generation Russian space stations included:

- 1977–1982 *Salyut-6* – Civilian
- 1982–1991 *Salyut-7* – Civilian (last staffed in 1986)

With the second-generation stations, the Soviet space station program evolved from short-duration to long-duration stays. Visiting crews relieved the monotony of a long stay in space.

Salyut-6 Key Facts

Highlights of the *Salyut-6* era include:

- The station received 16 cosmonaut crews, including six long-duration crews. The longest stay time for a *Salyut-6* crew was 185 days. The first *Salyut-6* long-duration crew stayed in orbit for 96 days, beating the 84-day world record for space endurance established in 1974 by the last American Skylab crew.
- The station hosted cosmonauts from Hungary, Poland, Romania, Cuba, Mongolia, Vietnam and East Germany.
- Twelve freighter spacecraft delivered equipment, supplies and fuel.

Show the cadets Figure 15L-3 and 15L-4.

Salyut-7 Key Facts

Highlights of the *Salyut-7* era include:

- *Salyut-7*, a near twin of *Salyut-6*, was home to 10 cosmonaut crews, including six long-duration crews. The longest stay time was 237 days.
- Cosmonauts from France and India worked aboard the station, as did the first female Russian space traveller since 1963.
- Thirteen freighter spacecraft delivered equipment, supplies, and fuel to *Salyut-7*.
- Two experimental transport logistics spacecraft, Cosmos 1443 and Cosmos 1686, docked with *Salyut-7*. Cosmos 1686 was a transitional vehicle, a transport logistics spacecraft redesigned to serve as an experimental space station module.
- *Salyut-7* was abandoned in 1986 and re-entered earth's atmosphere, burning up over Argentina in February, 1991.

Mir

Mir was a third-generation Russian space station which, after 1992, was shared with the US.

Mir means peace and community in Russian. The Mir space station contributed to world peace by hosting international scientists and American astronauts. It also supported a community of humans in orbit and symbolized the commonwealth of the Russian people.

Mir was constructed in orbit by connecting different modules, each launched separately from 1986 – 1996. During the Shuttle-Mir Program, Russia's Mir combined its capabilities with America's space shuttles. The orbiting Mir provided a large and liveable scientific laboratory in space. The visiting space shuttles provided transportation and supplies, as well as temporary enlargements of living and working areas, creating history's largest spacecraft.

Show the cadets Figures 15L-5 and 15L-6.

Magnificent to behold through the windows of a space shuttle, *Mir* was as big as six school buses. Inside, it looked more like a cramped labyrinth, crowded with hoses, cables and scientific instruments – as well as articles of everyday life, such as photos, children's drawings, books and a guitar. *Mir* commonly housed three crew members, but it supported as many as six, for up to a month. Except for two short periods, *Mir* was continuously occupied until August 1999.

The journey of the 15-year-old Russian space station ended March 23, 2001, as *Mir* re-entered the Earth's atmosphere near Nadi, Fiji and fell into the South Pacific. Despite its inconveniences, many cosmonauts and astronauts grew to love *Mir*, comparing it to a living being with qualities, needs and eccentricities.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS

Q1. Which Salyut space stations were considered to be second generation?

Q2. What does *Mir* mean in Russian?

Q3. Who were the first man and woman in space?

ANTICIPATED ANSWERS

A1. *Salyut-6* and *Salyut-7*.

A2. Peace and community.

A3. Yuri Gagarin and Valentina Tereshkova, respectively.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. Who was America's first astronaut to go into space?

Q2. When did *Apollo 11* land on the moon?

Q3. Who was chief of systems engineering for the Apollo Project?

ANTICIPATED ANSWERS

A1. Alan Shepard.

A2. July 20, 1969.

A3. Owen E. Maynard of Sarnia, Ontario.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Space exploration has taken great courage and ingenuity on the part of many people. Space exploration and the space race have changed the world for the better through international cooperation and promoting technological advancement.

INSTRUCTOR NOTES/REMARKS

N/A.

REFERENCES

(ISBN 978-0-75662-227-5) Graham, I. (2006). *Space Travel*. New York, NY: DK Publishing, Inc.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 3

EO C340.01 – IDENTIFY CANADIAN ASTRONAUTS

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Retrieve current information located at Annexes A to H in the instructional guide for EO M340.01 (Identify Canadian Astronauts, Section 1) or from the reference.

Create a slide of each astronaut's photograph from the same annexes.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to orient the cadets to Canadian astronauts, to generate interest in Canada's space program, and to emphasize the teaching points.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have identified Canadian astronauts.

IMPORTANCE

It is important for cadets to identify Canadian astronauts so that they can become familiar with the Canadian space program. The hard work that astronauts perform will illustrate the Air Force motto: *Per Ardua ad Astra*, as well as the rewards that can be achieved by men and women who accept the challenge of the stars.

Teaching Point 1 — **Discuss the Professional and Personal Profiles of Canadian Astronauts**

Time: 50 min — Method: Interactive Lecture

Ensure that astronauts covered in EO M340.01 (Identify Canadian Astronauts, Section 1) are not included in this lesson.

Discuss the following information about the remaining astronauts, using the information located at the respective annexes in the instructional guide for EO M340.01 (Identify Canadian Astronauts, Section 1) or retrieved from the reference, to include:

a. missions undertaken,

b. place and date of birth,

c. education,

d. professional experience,

e. special honours, and

f. affiliations.

CONFIRMATION OF TEACHING POINT 1

The cadets' participation in the interactive lecture will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. In what missions did these astronauts take part?

Q2. What role did these astronauts play on these missions?

Q3. What education and experience did these astronauts bring to the missions?

ANTICIPATED ANSWERS

A1. As per lesson content.

A2. As per lesson content.

A3. As per lesson content.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Space missions have a short history and a vast future. Cadets can stay current with the space program by frequently visiting websites of the Canadian Space Agency (CSA), the US National Aeronautics and Space Administration (NASA) and other organizations such as the European Space Agency (ESA).

INSTRUCTOR NOTES/REMARKS

The instructor shall obtain the latest biographical information for this EO. This material must be updated each year to reflect the Canadian Space Agency's recent activities.

A list shall be kept of astronauts that cadets have focused on to prevent repetition.

REFERENCES

C3-238 Canadian Space Agency. (2008). *Canadian Space Agency*. Retrieved February 9, 2008, from http://www.space.gc.ca/asc/eng/default.asp.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 4

EO C340.02 – DISCUSS THE CANADIAN SPACE PROGRAM

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of Annexes M and N.

Photocopy Annex O for each cadet.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to orient the cadets to the Canadian space program and to generate interest.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have discussed the Canadian space program.

IMPORTANCE

It is important for cadets to learn about the Canadian space program so they know that Canada participates in space exploration. The Canadian Space Agency (CSA) and its partners are leading the world in research involving space technologies. This information may also generate interest in the many scientific and technical careers involved in the exploration of space.

Teaching Point 1 | **Describe Canada's Involvement in Space Technologies**

Time: 10 min | Method: Interactive Lecture

Show slide of Annex M.

CANADA'S INVOLVEMENT IN SPACE TECHNOLOGIES

The CSA headquarters is located at the John H. Chapman Space Centre in Saint-Hubert, Que. Canada is involved in many aspects of space exploration. Canadian scientists and researchers are particularly interested with the development and testing of space technologies.

Canadian Space Agency, 2008, Canadian Space Agency Logo. Retrieved April 14, 2008, from http://upload.wikimedia.org/wikipedia/en/0/01/Canadian_Space_Agency_logo.png

Figure 15-4-1 CSA Logo

The David Florida Laboratory (DFL)

The David Florida Laboratory is Canada's world-class spacecraft assembly, integration and testing centre. Named in honour of one of Canada's pioneers in space research, C. David Florida, it is located west of Ottawa, Ont. The laboratory is maintained by the CSA. On a fee-for-service basis, the DFL is available for use by Canadian and foreign aerospace and telecommunication companies and organizations for testing hardware to be used in space. Since its creation in September 1972, DFL has made substantial contributions to satellite communications and remote sensing in Canada and continues to play an essential role in our space program.

The Canadian Analogue Research Network (CARN)

CARN is the organization that uses Canadian sites for field studies. These analogue sites approximate conditions that may exist or have existed on Mars and other planetary bodies such as the moon and the Solar System's icy moons.

They provide a unique opportunity to investigate geological and biological processes and hypothesize about planetary bodies. Analogue sites can be used to develop and test specific technology and to understand how to explore and live on other planets. The following are the first three CARN sites selected in 2005:

- Haughton-Mars Project Research Station, Devon Island, Nunavut, 75° 22' N, 89° 41' W;

- McGill Artic Research Station, Axel Heiberg Island, Nunavut, 79° 26’ N, 90° 46’ W; and
- Pavilion Lake, B.C., 50° 51’ N, 121° 44’ W.

It is envisioned that CARN will expand in future years with the inclusion of other selected sites.

Partnerships With the CSA

The CSA, formed in 1989, has many partners including international space agencies, industry, post-secondary researchers and educational projects.

One example of the CSA’s partnership with international space agencies is the CSA’s participation in the International Space Station (ISS). These partners include space agencies from Europe, Japan, Russia and the United States. All of these agencies have sent astronauts to the ISS and they each have ground crews and researchers that support each element of the project.

Industrial partners with the CSA include various Canadian technology companies. MD Robotics is one partner best known for developing and building the first Canadarm. MD Robotics is the prime contractor for the Mobile Servicing System, a sophisticated robotic system critical to assembly, maintenance and servicing of the ISS.

Another technology partner is EMS Technologies, Canada, Ltd. They are a leading provider of wireless, satellite and broadband communication products. EMS Technologies hardware has flown on more than 200 spacecraft.

Many partners of the CSA come from academic institutions. Most of these institutions have a space technology research faculty and their students may be granted money from the CSA to conduct their studies. These schools include the University of British Columbia and the University of Toronto.

The CSA takes great pride in their partnership with educational projects. CSA has a Youth Outreach Group which develops and organizes special educational projects for teachers and youth. CSA believes that students in primary and secondary schools are Canada’s next generation of space explorers and researchers. Some of these students are given opportunities to pursue their studies and begin a career in science and technology.

For more information on the CSA and its Youth Outreach Group, access their website at www.space.gc.ca.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. Where is DFL located?

Q2. Analogue sites are used to develop what?

Q3. List some CSA international partners.

ANTICIPATED ANSWERS

A1. It is located west of Ottawa, Ont.

A2. Analogue sites can be used to develop and test specific space technology.

A3. Space agencies from Europe, Japan, Russia and the United States.

Teaching Point 2	Describe CSA Missions
Time: 15 min	Method: Interactive Lecture

CSA MISSIONS

CSA has participated in many space missions with its partners. Canadian astronauts or Canadian technology has gone into space with agencies from the United States, Russia, Europe and Japan. There are four basic types of CSA missions.

Telecommunications

Canada is the second largest country on earth and finding ways to communicate over great distances is a challenge. Telecommunication satellites are the most economical way to connect Canadian communities. Being able to keep all places in the country connected with advanced telecommunication services assists every Canadian in competing in the global marketplace. These telecommunication satellites assist search and rescue teams, provide ships and aircraft with geopositioning information, and connect instructors with classrooms across the country.

Ask cadets to list instances where they have probably used telecommunication satellites (eg, long distance cell phone conversations, satellite TV, etc).

Canada's most famous telecommunication satellites are the ANIK series, which were launched in the 1980s, 1990s and as recently as 2004.

Earth Observation

Ask cadets to list ideas about what satellites are seeing when they look at the earth.

Canada's earth-observation initiatives enhance our understanding of the planet and its environment. By observing the earth from space, essential information about oceans, ice, land environments and the atmosphere is gathered. Earth-observation satellites collect data that assist scientists monitoring and protecting the environment and managing resources. Some earth-observation satellites gather data that is used by the government to ensure the safety and security of Canadians. Satellite imagery and expertise is also used for global humanitarian efforts. Some examples of earth-observation satellites include:

Radarsat-1. Launched in 1995, Radarsat-1 provides the world with an operational radar satellite system capable of the timely delivery of large amounts of data. Radarsat-1 quickly acquires images of the earth day or night, in all weather conditions and through cloud cover, smoke and haze.

Envisat. Launched in 2002, Envisat collects specific data for the scientific community in order to better understand climatic processes. Data is collected on ocean-atmosphere heat exchange, interaction between the atmosphere and land or ice surfaces and the composition of the atmosphere and its associated chemical processes. This data helps scientists improve climate models.

Cloudsat. Launched in 2006, Cloudsat gathers new data and improve our knowledge of clouds and their effect on climate. Traditional satellites studying the atmosphere can portray the cloud surface accurately, but are limited to a two-dimensional representation of cloud cover. No data has been available on cloud thickness that would help determine the volume and quantity of water, snow, or ice that clouds contain. Cloudsat was developed by National Aeronautics and Space Administration (NASA) in partnership with the CSA.

Radarsat-2. Launched in 2007, Radarsat-2 is Canada's next generation commercial satellite and offers powerful technical advancements. Radarsat-2 has higher resolution cameras and better discrimination of surface types than Radarsat-1. Radarsat-2 will enhance marine surveillance, ice monitoring, disaster management, environmental monitoring, resource management and mapping in Canada and around the world.

Space Exploration

The CSA is involved with exploring space. Canadian astronauts have been on many missions in various space shuttles and continue to investigate the solar system one small step at a time.

> Have the cadets name Canadian astronauts.

Canada is renowned for the exceptional instruments in its science satellites. Some of these satellites collect data that will expand our understanding of the origin, formation, structure and evolution of celestial bodies and the universe.

Another example of the CSA exploring space is the use of Canadian technology in various Martian missions. A Canadian weather station was delivered to an arctic region on Mars in 2008. The instruments measure pressure and temperature, and assess local climate patterns as well as dust, clouds and fog in the lower atmosphere.

Canadians are developing integrated communications networks that will be needed to run a successful international mission on Mars. This will enable Canadians to play a key communications role in future manned exploration to the Red Planet and beyond.

The CSA is supporting a study that focuses on the development of biological air filters for maintaining air quality in a closed system. This research may be used for life support systems and will be crucial for any long duration space exploration missions.

Space Medicine

> Show slide of Annex N.

Space medicine combines many medical specialties to examine the effects of spaceflight on humans and prevent problems associated with living in a unique, isolated, and extreme environment like space. The CSA has a medical department called the Operational Space Medicine (OSM) Group. It is responsible for the health and safety of Canadian astronauts. Studies have shown that the longer an astronaut remains in space, the more changes will take place in the body. While in space many of these changes tend not to be problematic. It is on their return to earth where the effects of living in space are felt. Some examples of effects may be reduced blood volume, diminished reflexes, loss of bone mass and radiation-induced health problems. OSM group is studying many of these changes to try to overcome them in order to send astronauts on longer flights.

Canadian Space Agency, 2008, Operational Space Medicine Logo. Retrieved April 14, 2008, from http://www.space.gc.ca/asc/eng/astronauts/osm_crest.asp

Figure 15-4-2 OSM Logo

Ask cadets if they think that space medicine will help people on earth and how that will happen.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. Why are telecommunication satellites so important to the CSA?

Q2. How can earth-observation satellites assist scientists monitoring and protecting the environment and managing resources?

Q3. Name the CSAs medical group.

ANTICIPATED ANSWERS

A1. Telecommunication satellites are the most economical way to connect Canadian communities.

A2. By collecting data.

A3. OSM Group.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. Where are the three CARN sites in Canada?

Q2. What are the four basic types of missions that CSA participates in?

Q3. Where was a Canadian weather station delivered in 2008?

ANTICIPATED ANSWERS

A1. Devon Island, Nunavut, Axel Heiberg Island, Nunavut, and Pavilion Lake, B.C.

A2. Telecommunications, earth observation, space exploration and space medicine.

A3. To an arctic region on Mars.

Distribute Annex O to each cadet.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Even without any domestic launch capabilities of our own, Canadians have made a large impact on space exploration. There are many scientific and technical careers involved in the exploration of space and the CSA and its partners are leading the world in research involving space technologies.

INSTRUCTOR NOTES/REMARKS

This material must be updated each year to reflect CSA progress.

REFERENCES

C3-238 Canadian Space Agency. (2008). *Canadian Space Agency*. Retrieved February 9, 2008, from http://www.space.gc.ca/asc/eng/default.asp.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 5

EO C340.03 – DISCUSS UNMANNED SPACE EXPLORATION

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of figures located at Annexes P to S.

Photocopy the handout of page 15Q-4 for each cadet.

Photocopy the *Moons* video worksheet located at page 15S-1.

Cue the video *Moons*.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to orient the cadets to unmanned space exploration, generate interest, and emphasize the teaching points.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have discussed unmanned space exploration.

IMPORTANCE

It is important for cadets to learn about unmanned space exploration because it will become increasingly significant as developing technologies and resource depletion move humanity's focus beyond Earth.

Teaching Point 1 | **Describe the History of Earth Satellites**

Time: 15 min | Method: Interactive Lecture

DEVELOPMENT OF LAUNCH CAPABILITY

To achieve a low earth orbit an object must accelerate to 8 000 m/s. This was first done in 1957 by two liquid-propellant rockets: the Soviet R-7 and America's Jupiter-C.

In 1898, Konstantin Tsiolkovsky (1857–1935), proposed the idea of space exploration by rocket. In 1903, Tsiolkovsky suggested the use of liquid propellants for rockets in order to achieve greater range. For his ideas, careful research and great vision, Tsiolkovsky has been called the father of modern astronautics.

> **Astronautics.** The science of space travel.

Early in the 20th century, an American, Robert Goddard (1882–1945), conducted practical experiments in rocketry with solid-propellant rockets.

> In 1919, Goddard published a pamphlet, *A Method of Reaching Extreme Altitudes*. This was a mathematical analysis of what is today called the meteorological sounding rocket.

Goddard became convinced that a rocket could be better propelled by liquid fuel than by solid fuel. Fuel and oxygen tanks, turbines and combustion chambers would be needed. Goddard achieved the first successful flight with a liquid-propellant rocket on March 16, 1926. The rocket flew for only two and a half seconds, climbed 12.5 m and landed 56 m away in a cabbage patch. Goddard's gasoline rocket was the forerunner of modern rocketry.

Goddard's experiments in liquid-propellant rockets continued for many years. His rockets became bigger, flew higher and carried more cargo. For his achievements, Robert Goddard has been called the father of modern rocketry.

> Show the cadets Figures 15P-1 and 15P-2. Point out the major components of the liquid-fuelled rocket in Figure 15P-1 corresponding to the parts listed in Figure 15P-2.

SOVIET SPUTNIK MISSION

On October 4, 1957, just 12 years after Goddard's death, the world was stunned by the news of an Earth-orbiting artificial satellite launched by the Soviet Union. Sputnik-1 was the first successful entry in a race for space. Sputnik-1 was a very simple machine. Its mission was to orbit and send repetitive radio signals.

> Show the cadets Figures 15P-3 and 15P-4.

The Soviet scientists and engineers launched Sputnik-1 into a low earth orbit by the use of a modified R-7 two-stage rocket. It was the first entirely successful R-7 flight. The R-7 was developed by the military as a means of delivering warhead payloads across vast distances. Such a vehicle was perceived to be necessary for national defence.

Show the cadets Figures 15P-5 and 15P-6.

UNITED STATES' EXPLORER MISSION

A few months after the launch of Sputnik-1 the United States followed with a satellite of its own, Explorer-1, designed and built by the Jet Propulsion Laboratory (JPL) of the California Institute of Technology. This satellite was launched into orbit by the US Army on January 31, 1958, using a Jupiter-C rocket, which was also developed with warheads in mind. In addition to a radio transmitter, Explorer-1 had a scientific instrumentation package designed and built by Dr. James Van Allen of the State University of Iowa. The instruments were designed to measure the intensity of cosmic radiation in space.

The discovery of the Van Allen Belts by the Explorer satellites was considered to be one of the outstanding discoveries of the International Geophysical Year (1958).

The Jupiter-C launcher was a three-stage rocket. Before the successful launch of Explorer-1, the Jupiter-C was used to loft payloads to various altitudes.

Show the cadets the flight history of Jupiter-C located at Annex P. Point out the work that preceded the successful launch of Explorer-1.

More Jupiter-C history can be found at website http://history.nasa.gov/sputnik/expinfo.html

The three-stage Jupiter-C, with Explorer-1 mounted on top, was over 21 m (71 feet) high.

Show the cadets Figures 15P-7 and 15P-8.

Nine months after the launch of Explorer-1, in October 1958, the United States formally organized its space program by creating the National Aeronautics and Space Administration (NASA). NASA became a civilian agency with the goal of peaceful exploration of space for the benefit of all humankind.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. Who has been called the father of modern astronautics?

Q2. Who has been called the father of modern rocketry?

Q3. When was NASA created?

ANTICIPATED ANSWERS

A1. Konstantin Tsiolkovsky has been called the father of modern astronautics.

A2. Robert Goddard has been called the father of modern rocketry.

A3. October 1958.

Teaching Point 2	**Describe the Twin Voyager Spacecraft**
Time: 20 min	Method: Interactive Lecture

THE TWIN VOYAGER SPACECRAFT

The twin spacecraft Voyager-1 and Voyager-2 were launched by NASA in the summer of 1977 from Cape Canaveral, Florida. The Voyagers were to conduct close-up studies of Jupiter, Saturn, Saturn's rings and the larger moons of the two planets. To accomplish their two-planet mission, the spacecraft were built to last five years. As the mission went on, and with the successful achievement of all its objectives, the additional flybys of the two outermost giant planets, Uranus and Neptune, also proved possible.

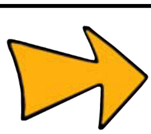
The Planetary Voyage

As the spacecraft flew across the solar system their two-planet mission became four. Their five-year lifetimes stretched to 12 and then to 30 years.

The Voyager mission was designed to take advantage of a rare geometric arrangement of the outer planets in the late 1970s and the 1980s, which allowed for a four-planet tour with minimum propellant and time.

Eventually, Voyager-1 and Voyager-2 would explore all four outer planets of the solar system, 48 of their moons and the unique systems of rings and magnetic fields those planets possess. Had the Voyager mission ended after the Jupiter and Saturn flybys, it still would have provided the material to rewrite astronomy textbooks. Having doubled their itineraries, the Voyagers returned information over the years that has revolutionized the science of planetary astronomy, helping to resolve key questions while raising new ones about the origin and evolution of the planets in our solar system.

Show the cadets Figure 15Q-1.



The layout of Jupiter, Saturn, Uranus and Neptune shown in Figure 15Q-1, which occurs about every 175 years, allows a spacecraft to swing from one planet to the next without the need for large on-board propulsion systems. The flyby of each planet bends the spacecraft's flight path and increases its velocity enough to send it to the next destination. By using this "gravity assist" technique, first demonstrated with NASA's Mariner-10 Venus/Mercury mission in 1973–74, the flight time to Neptune was reduced from 30 years to 12.

Show the cadets Figure 15Q-2.

The original Voyager mission to Jupiter and Saturn sent Voyager-1 to Jupiter on March 5, 1979 and Saturn on November 12, 1980, followed by Voyager-2 to Jupiter on July 9, 1979, and Saturn on August 25, 1981. The two spacecraft's paths differed in that:

- Voyager-1's trajectory was designed to send the spacecraft close to Saturn's large moon, Titan, and behind Saturn's rings.
- Voyager-2 was aimed to fly by Saturn at a point that would automatically send the spacecraft in the direction of Uranus.

After Voyager-2's successful Saturn encounter, it was shown that the spacecraft would likely be able to fly to Uranus with all instruments operating. Subsequently, NASA also authorized the Neptune leg of the mission, which was renamed the Voyager Neptune Interstellar Mission. Voyager-2 encountered Uranus on January 24, 1986, returning detailed photos and other data about the planet, its moons, magnetic field and dark rings.

Voyager-1 continues outward, conducting studies in space beyond the outer planets. Eventually, its instruments may be the first of any spacecraft to sense the heliopause.

The heliopause is the boundary between the end of the Sun's magnetic influence and the beginning of interstellar space.

After Voyager-2's closest approach to Neptune on August 25, 1989, the spacecraft flew a course taking it into interstellar space. Reflecting the Voyagers' new destinations, the project is now known as the Voyager Interstellar Mission.

The Voyager Interstellar Mission (VIM)

The heliopause is the boundary between the solar and the interstellar winds. This is a definitive and unambiguous frontier that the Voyagers will approach and pass through.

Show the cadets Figure 15Q-3.

Voyager-1 crossed the solar wind termination shock in December 2004 and entered into the heliosheath, the turbulent region leading up to the heliopause. The Voyagers should cross the heliopause 10 to 20 years after reaching the termination shock. In 2007, Voyager-2 was observing preshock phenomena, indicating that it was close to the termination shock.

The solar wind termination shock is where the 1 600 000 km/h solar wind slows to about 400 000 km/h on contact with the interstellar winds.

When the Voyagers cross the heliopause, hopefully while the spacecraft are still able to send science data to Earth, they will be in interstellar space. Once Voyager is in interstellar space, it will be immersed in matter that came from explosions of nearby stars.

Show the cadets Figure 15Q-4.

Both spacecraft will continue to study ultraviolet sources among the stars, and the fields and particles instruments aboard the Voyagers will continue to explore the boundary between the sun's influence and interstellar space. The Voyagers are expected to return valuable data for at least another decade. Communications will be maintained until the Voyagers' power sources can no longer supply enough electrical energy to power critical subsystems.

The Voyagers have enough electrical power and thruster fuel to operate until at least 2020. By that time, Voyager-1 will be 19.9 billion km (12.4 billion miles) from the sun and Voyager 2 will be 16.9 billion km (10.5 billion miles) away. The Voyagers are destined – perhaps eternally – to wander the Milky Way.

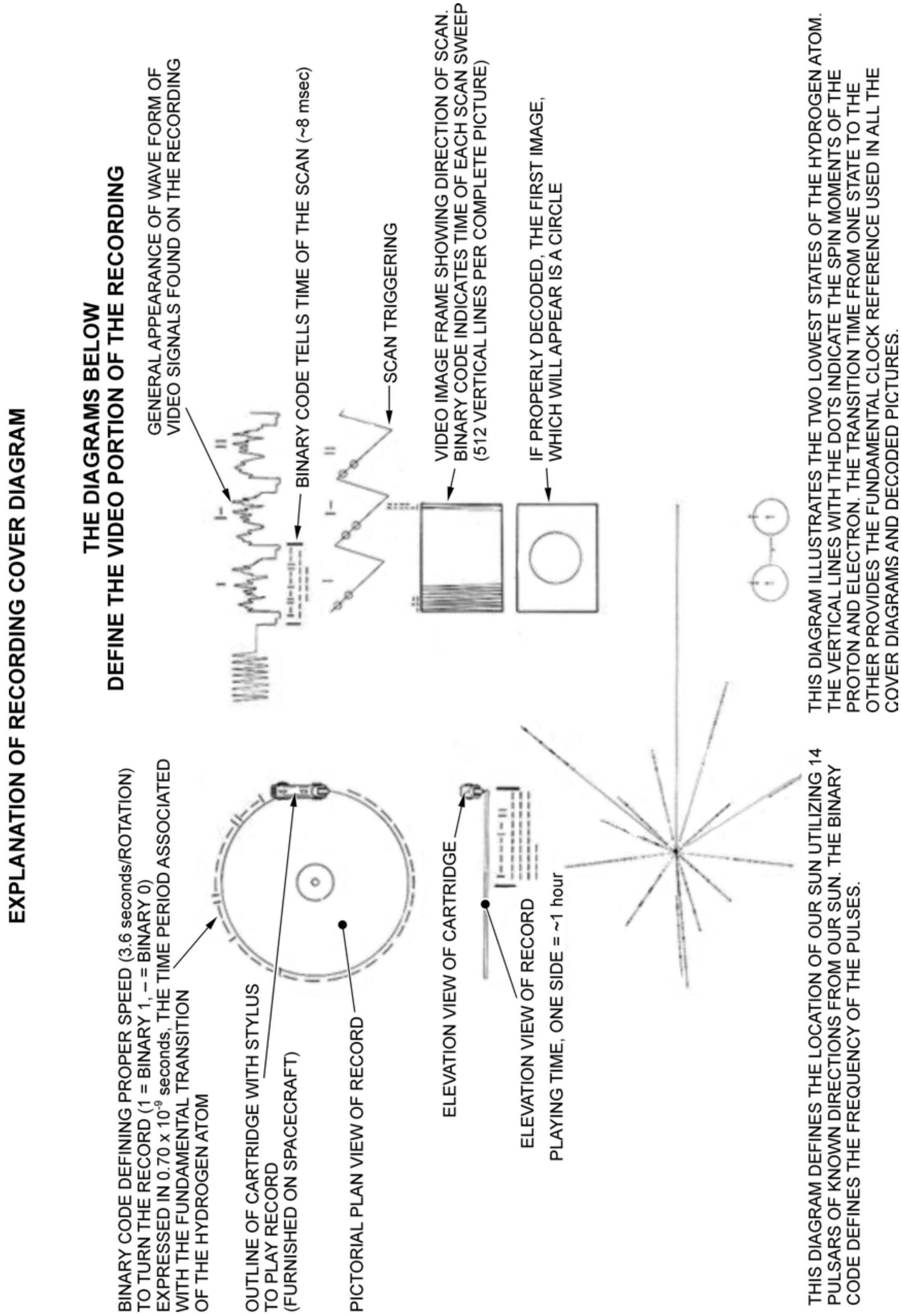
For current distances of the Voyagers, check mission weekly reports at NASA website http://voyager.jpl.nasa.gov/mission/weekly-reports/index.htm.

The Golden Record

Show the cadets Figure 15Q-5.

NASA placed a message on board Voyager-1 and -2 intended to communicate a story of our world to any extraterrestrials that find the spacecraft. A phonograph record – a 30 cm gold-plated copper disk containing sounds and images selected to portray the diversity of life and culture on Earth, carries the Voyager message. Instructions, in symbolic language, explain the origin of the spacecraft and indicate how the record is to be played. Once the Voyager spacecraft left the solar system (by 1990, both were already beyond the orbit of Pluto), they were in empty space with only the solar wind for company. It will be 40 000 years before they make a close approach to any other planetary system.

Explain symbols of the recording cover diagram as shown in Figure 15-5-1. This is information that extraterrestrials would need to understand the golden record.



"Voyager: The Intersteller Mission", by NASA, 2003, The Golden Record. Retrieved April 8, 2008, from http://voyager.jpl.nasa.gov/spacecraft/goldenrec1.html

Figure 15-5-1 Key to the Golden Record

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. In what year were the two Voyager spacecraft launched?

Q2. Which Voyager spacecraft visited Saturn?

Q3. For whom was the golden record prepared?

ANTICIPATED ANSWERS

A1. 1977.

A2. Both of them: Voyager-1 in November 1980 and Voyager-2 in August 1981.

A3. Extraterrestrials.

Teaching Point 3	**Describe Unmanned Space Exploration**
Time: 20 min	Method: Interactive Lecture

MISSIONS TO PLANETS WITHIN THE SOLAR SYSTEM

Launched on March 2, 1972, Pioneer-10 was the first spacecraft to travel through the asteroid belt, make direct observations and obtain close-up images of Jupiter. During its Jupiter encounter, Pioneer-10 imaged the planet and its moons and took measurements of Jupiter's magnetic field, atmosphere and interior. These measurements of the environment near Jupiter were crucial in designing later spacecraft.

Pioneer-10 ended its successful mission on March 31,1997. Pioneer-10's weak signal continued to be tracked by the NASA's Deep Space Network as part of an advanced concept study of communication technology in support of NASA's future interstellar probe mission. The power source on Pioneer-10 finally failed in 2003. Pioneer-10 will continue into interstellar space, heading for the red star Aldebaran, which forms the eye of Taurus (The Bull). It will take Pioneer-10 over 2 million years to reach Aldebaran.

THE PHOENIX MARS MISSION

Show the cadets Figure 15R-1.

The Phoenix Mars Lander is the first spacecraft designed to visit a polar region of Mars at ground level. Its mission is to explore the soil and atmosphere of the polar regions of Mars to determine if the environment could be hospitable to life.

Show the cadets Figures 15R-2, 15R-3 and 15R-4.

Phoenix was launched from the Kennedy Space Center on August 3, 2007, to land near the northern polar cap of Mars on May 25, 2008, in an area known as Vastitas Borealis. At 125 km (78 miles) above the surface, Phoenix entered the thin Martian atmosphere. It slowed itself down by using atmospheric friction. A heat shield protected the lander from the extreme temperatures generated during entry.

> Show the cadets Figures 15R-5, 15R-6 and 15R-7.

Antennas located on the back of the shell which encases the lander are used to communicate with one of three spacecraft currently orbiting Mars. These orbiters relay signals and landing info to Earth.

Mission Characteristics

In the continuing search for water on Mars, the polar regions are attractive because water ice has been found there. The Phoenix landing site was chosen farther north than previous missions, at a latitude equivalent to that of northern Canada, between 65 and 72 degrees north latitude.

To study Martian atmospheric processes, Phoenix was designed to scan the atmosphere up to 20 km (12.4 miles) in altitude, to obtain data about the formation, duration and movement of clouds, fog, and dust plumes. This capability includes temperature and pressure sensors.

> Show the cadets Figure 15R-1. Point out the robotic arm.

Phoenix is equipped with a 2.35 m robotic arm to dig for clues about the history of water on Mars. Although the Phoenix mission will not be capable of moving about on Mars, the Phoenix Lander is designed to investigate by scooping up samples for analysis by its on-board chemistry set. This analysis includes whether the soil is salty, alkaline, and/or oxidizing, and then tests for complex organic molecules necessary for life.

> Why would we search for water? Water is a key clue to the most critical scientific questions about Mars. Water is a precursor for life as we know it, a potential resource for human explorers and a major agent of climate and geology.

Canada's Lidar Weather Station

Canada's contribution to the Phoenix mission was a meteorological station that records the daily weather of the Martian northern plains using temperature, wind and pressure sensors, as well as a light detection and ranging (lidar) instrument. The weather station helps improve models of the Martian climate and predict future weather processes, paving the way for future exploration missions. Resembling a brilliant green laser, the lidar probes what is known as the "boundary layer" of the Martian atmosphere (the turbulent layer of the atmosphere about 7–10 km above the surface) and provides information about the structure, composition and optical properties of clouds, fog and dust in the lower atmosphere (up to 20 km above the landing site).

THE CASSINI-HUYGENS MISSION TO SATURN

Four NASA spacecraft have been sent to explore Saturn. Pioneer-11 was first to fly past Saturn in 1979. Voyager-1 flew past a year later, followed by its twin, Voyager-2, in 1981. The fourth spacecraft to visit Saturn was Cassini-Huygens.

ACTIVITY

Time: 10 min

OBJECTIVE

The objective of this activity is to have cadets learn an astrophysicist's perspective of the Cassini-Huygens mission.

RESOURCES

- Five-minute video *Moons* (Reference C3-251),
- Laptop computer,
- Multimedia projector, and
- Projection screen.

ACTIVITY LAYOUT

N/A.

ACTIVITY INSTRUCTIONS

1. Distribute the *Moons* video worksheet located at Annex S.
2. Have the cadets read all the questions before the video is started.
3. Have the cadets fill out the worksheet as they watch *Moons*.
4. Correct the answers on the worksheet using the answer key located at Annex T.

SAFETY

N/A.

Mission Summary

Cassini is the fourth spacecraft to explore Saturn, but the first to explore the Saturnian system of rings and moons from orbit. Cassini carried the Huygens probe to explore the atmosphere of Titan, one of Saturn's more than 60 moons.

Cassini-Huygens' journey to Saturn began on October 15, 1997. The spacecraft was sent to Venus for the first of four planetary gravity assists designed to boost Cassini-Huygens toward Saturn. The spacecraft entered orbit around Saturn on June 30, 2004 and immediately began sending back intriguing images and data.

Show the cadets Figure 15S-1. Point out the Saturnian moons in Figure 15S-1, with particular attention to Titan near the right side of the picture.

Saturn has the most extensive and complex ring system in our solar system. It is made up of billions of particles of ice and rock, ranging in size from grains of sugar to houses. The rings travel at varying speeds. There are hundreds of individual rings, which are believed pieces of shattered moons, comets and asteroids. Each of the billions of ring particles orbit the planet on their own path.

Huygens' Descent to Titan

The Huygens probe was released from the Cassini probe and dove into the thick atmosphere of Titan in January 2005. The sophisticated instruments on both spacecraft provided scientists with data and images of this mysterious region of our solar system.

Show the cadets Figures 15S-2 and 15S-3.

It was discovered that Saturn's orange moon, Titan, has hundreds of times more liquid hydrocarbons than all the known oil and natural gas reserves on Earth. The hydrocarbons rain from the sky, collecting in vast deposits that form lakes and dunes. Individual lakes have more oil than the entire Earth.

Cassini Orbiter Flybys

Cassini-Huygens looped around the Sun twice. On the first orbit it flew close behind Venus in its solar orbit, where it received a gravity assist. The next orbit provided two gravity assists from a second flyby of Venus in June 1999 and of Earth in August 1999. With these three gravity assist boosts, Cassini-Huygens had enough orbital momentum to reach the outer Solar System. One last gravity assist manoeuvre from Jupiter on December 30, 2000 gave Cassini-Huygens the final thrust of energy it needed to reach Saturn. The mission arrived at Saturn in July 2004.

Cassini orbited Saturn for four years, sending back data to Earth. Cassini completed 75 orbits of the ringed planet, 44 close flybys of the mysterious moon Titan, and numerous flybys of Saturn's other icy moons. During a flyby of Saturn's moon Enceladus, it was discovered that there is so much liquid water under Enceladus' frozen surface that it erupts at 400 m per second in geysers that rise into space. Flying at 15 km per second, Cassini passed through the watery plumes at an altitude of 200 km.

Show the cadets Figures 15S-4 and 15S-5.

Whether these and other facts about the Saturnian system turn out to be useful to humans remains to be seen; the European Space Agency states that there is more work left to be done for future scientists.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. What is the mission of the Phoenix lander?

Q2. Will the Phoenix mission be capable of moving about on Mars?

Q3. Why would we search for water on Mars, Titan or Enceladus?

ANTICIPATED ANSWERS

A1. To explore the soil and atmosphere of the polar regions of Mars to determine if the environment could be hospitable to life.

A2. No.

A3. Water is a precursor for life as we know it, a potential resource for human explorers and a major agent of climate and geology.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. What year was Sputnik-1 launched into space?

Q2. What outstanding discovery of the International Geophysical Year did Explorer provide?

Q3. What type of assist did Cassini-Huygens use four times to accelerate?

ANTICIPATED ANSWERS

A1. 1957.

A2. The Van Allen Belts.

A3. Gravity assist.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

The half-century from the launch of Sputnik in late 1957 to Huygen's Titan descent in early 2005 saw remarkable accomplishments in space exploration. These were possible due to technological advances and a tenacious refusal to accept defeat despite setbacks.

INSTRUCTOR NOTES/REMARKS

TP 2 must be updated each year to reflect current events.

Model kits of spacecraft may be purchased online as training aids.

REFERENCES

C3-238 Canadian Space Agency. (2008). *Canadian Space Agency*. Retrieved February 9, 2008, from http://www.space.gc.ca/asc/eng/default.asp.

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C3-242 NASA. (2008). *NASA Cassini-Huygens Homepage*. Retrieved February 9, 2008, from http://saturn.jpl.nasa.gov/home/index.cfm.

C3-251 European Space Agency. (2008). ESA: Multimedia Gallery Videos. *Moons*. Retrieved April 5, 2008, from http://www.esa.int/esa-mmg/mmg.pl?mission=Cassini-Huygens&type=V.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 6

EO C340.04 – DESCRIBE ELEMENTS OF THE NIGHT SKY

Total Time: 30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of Figures 15U-1 to 15U-4.

Visit the National Research Council (NRC) website (Reference C3-221) and retrieve a planisphere star chart, make one copy for each cadet. Prepare one planisphere for use in TP1.

Photocopy Annex V for each cadet.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to orient the cadets to elements of the night sky, to generate interest and emphasize the teaching points.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have described elements of the night sky.

IMPORTANCE

It is important for cadets to be able to describe the elements of the night sky so they may apply the knowledge acquired while viewing the night sky or during online stargazing. These activities may generate interest in astronomy.

Teaching Point 1 | **Describe Fixed Elements of the Night Sky**

Time: 15 min | Method: Interactive Lecture

VISIBLE STARS

Stars are large spherical bodies, many times the size of Earth, composed of hydrogen and heavy elements that are compressed and heated by the pressure of gravitation. This heat and pressure causes nuclear reactions, which make the star visible. A star's gravity then compresses the ongoing nuclear explosion, which prevents the star from disintegrating.

Although the smallest stars are many times larger than Earth, they are so far from Earth that, except for the Sun, they appear as mere luminous points. Their great distance also makes them appear fixed in the sky even though each star is actually moving in a vast orbit around the centre of the galaxy.

> Star brightness is called magnitude. The lower the magnitude, the brighter the object. The brightest star visible in the night sky is Sirius, classified as a magnitude of −1.

Presently, the scale of visibility ranges from a faint magnitude 30, which are objects that can be detected by the Hubble Space Telescope, to a bright magnitude -27 which corresponds with the Sun. On this scale, the Sun is 16 trillion times brighter than a magnitude 6 star.

Ancient peoples imagined patterns using individual stars. One of the most useful and easily identifiable patterns uses seven bright stars: Alkaid, Mizar, Alioth, Megrez, Phekda, Merak and Dubhe. Together these stars form the Big Dipper, which is part of the constellation Ursa Major.

> Show the cadets Figure 15U-1.

In the mid-northern hemisphere, the Big Dipper can be seen at any time of the year and at any time of night from everywhere in Canada. The Big Dipper is the most prominent stellar configuration in the night sky. It can easily be identified by untrained observers, making it the ideal reference point for finding other elements of the night sky.

The Big Dipper swings around the sky as the Earth rotates through day and night, so it appears in different orientations. Every 24 hours it circles the North Star (Polaris).

> Show the cadets Figure 15U-2.

> Show the cadets Figure 15U-3.

CONSTELLATIONS

Constellations are patterns of stars partitioned and named long ago by our ancestors.

Of the 88 constellations recognized by the International Astronomical Union approximately one quarter of these are in the southern sky and not visible from mid-northern latitudes. About half of the remaining constellations are faint and hard to distinguish.

Hand out Annex U to each cadet.

Many of the visible and well-known constellations are shown in this handout. All constellations, including Ursa Major (the Big Dipper), circle the sky every 24 hours, with Polaris – the North Star – at the centre of the circle.

A planisphere may be used to locate constellations by holding it so the time of year is at the top. This represents the orientation of the constellations as seen at midnight. Remember that the constellations swing around Polaris once every 24 hours and also once every 12 months. A planisphere is only correct at midnight. At midnight, the stars at the top of the planisphere will be in front of an observer facing north and the stars at the bottom of the planisphere will be in front of an observer facing south.

Distribute the two parts of a planisphere retrieved from the NRC website http://www.nrc-cnrc.gc.ca/docs/education/planisphere_e.pdf to each cadet. Demonstrate how to assemble a planisphere using a prepared copy.

ACTIVITY

Time: 5 min

OBJECTIVE

The objective of this activity is to have the cadets use the Big Dipper to locate other elements of the night sky.

RESOURCES

Handout of Figure 15U-4 showing the seasonal locations of the constellations in the night sky.

ACTIVITY LAYOUT

N/A.

ACTIVITY INSTRUCTIONS

1. Have the cadets rotate their handout so that today’s date is located at the top (midnight tonight).
2. Have the cadets find the Big Dipper in Ursa Major.
3. When all cadets have found Ursa Major, have them find Polaris (at centre).

4. When all cadets have found Polaris, have them find the star Sirius in the constellation Canis Major (about July 5 position near the rim).
5. Have the cadets locate their own sign of the Zodiac (hint: midnight on their birthday).

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 1

The cadets' participation in this activity will serve as the confirmation of this TP.

Teaching Point 2 — **Describe Moving Objects of the Night Sky**

Time: 10 min — Method: Interactive Lecture

SATELLITES

There are many moving lights in the sky, including aircraft and satellites. A satellite is any celestial body orbiting the earth, but most satellites that are large enough to be seen from the surface of the Earth are man-made. Aircraft have a flashing white light to identify their position as well as red and green wing tip lights, while man-made satellites orbiting the Earth are star-like and do not twinkle. They appear to shine with a steady white glow due to sunlight reflecting off the metal surfaces. Satellites are more prominent during the spring and summer when the Earth's shadow is lower in the sky. Sightings are greater just after dark and drop off close to midnight. Satellites move in a linear fashion at a regular pace, though most observers tend to view their motion as wavy or jerky. Some of these orbiting objects are inhabited by people.

To find the International Space Station (ISS) or any space shuttle, go to NASA's website http://spaceflight.nasa.gov/realdata/sightings/. Select your location from the menu and find out where to look in the sky.

Show the cadets Figure 15V-1.

The times that the spacecraft will be visible are listed. The NASA website uses the following format:

THE FOLLOWING ISS SIGHTINGS ARE POSSIBLE FROM FRI FEB 08 TO WED FEB 20

SATELLITE	LOCAL DATE/TIME	DURATION (MIN)	MAX ELEV (DEG)	APPROACH (DEG-DIR)	DEPARTURE (DEG-DIR)
ISS	Fri Feb 08/07:04 PM	2	51	20 above WNW	51 above N

HUMANSPACEFLIGHT: Sighting opportunities by NASA, 2003. Retrieved February 8, 2008, from http://spaceflight.nasa.gov/realdata/sightings/

Figure 15-6-1 Building the ISS

The first column lists the spacecraft; the second column gives the date and time of the viewing. The third column shows how long the viewing will be possible. The fourth column shows the maximum height above the horizon that the spacecraft will be seen. The fifth column shows the direction in which the spacecraft will first appear and the final column shows the direction in which it will be last visible.

Hand out Annex V to each cadet.

PLANETS

The easiest way to observe planets is to know when and where to expect them. This information is readily available on astronomical calendars, observer handbooks and most astronomy resource books or can be easily found on the internet.

Planet	Magnitude	Description
Mercury	0	Mercury is only visible for a few weeks each year because of its orbit. It is yellow and can be seen just after sunset or just before sunrise.
Venus	−4	Venus is visible in the early evening or the early morning for several months each year. It cannot be seen more than four hours after sunset or before sunrise. Venus appears white and is very bright.
Mars	−3 to 1	Because the distance from Earth varies, so does the apparent brightness of Mars. It appears to be a rusty colour due to the light reflecting off the red planet. Mars travels across half the sky in one year, making it interesting to track.
Jupiter	−2 to −3	Jupiter is brighter than most stars but is still not as bright as Venus. Jupiter appears creamy white and can occasionally be seen all night long.
Saturn	0	Saturn is often mistaken for a star since its brightness matches that of some of the brighter stars. Saturn appears as a pale yellow orb.
Uranus	6	Uranus has a distinct blue-green hue.
Neptune	8	Neptune appears to be approximately the same size of Uranus, though it has a deeper blue hue. They can be differentiated by their position in the sky.

Five planets are visible to the naked eye: Mercury, Venus, Mars, Jupiter and Saturn. Uranus and Neptune must be viewed through binoculars or a telescope.

Planets, like satellites, do not twinkle. Remember, the higher the brightness magnitude, the dimmer the planet – just like stars.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. What is a satellite?

Q2. When is the planet Venus visible?

Q3. How many planets are visible to the naked eye?

ANTICIPATED ANSWERS

A1. A satellite is any celestial body orbiting the earth.

A2. Venus is visible in the early-evening or the early-morning.

A3. Five.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. What makes stars visible?

Q2. What are constellations?

Q3. What is the easiest way to observe planets?

ANTICIPATED ANSWERS

A1. Sustained nuclear reactions caused by the pressure and heat of gravity.

A2. Constellations are patterns of stars partitioned and named long ago by our ancestors.

A3. The easiest way to observe planets is to know when and where to expect them.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Knowledge about elements of the night sky is useful when viewing the night sky or during online stargazing. Recognizing these elements will enhance the enjoyment of amateur astronomy.

INSTRUCTOR NOTES/REMARKS

This EO may be conducted with EO C390.09 (Identify Elements of the Night Sky, Chapter 18, Section 14).

REFERENCES

C3-179 (ISBN 1-55209-302-6) Dickenson, T. (2001). *Night Watch: A Practical Guide to Viewing the Universe*. Willowdale, ON: Firefly Books.

C3-180 (ISBN 1-55297-853-2) Scagell, R. (2004). *Firefly Planisphere: Latitude 42 Deg N*. Willowdale, ON: Firefly Books.

C3-221 National Research Council of Canada. (2007). *Explore the Night Sky*. Retrieved December 3, 2007, from http://www.nrc-cnrc.gc.ca/eng/education/astronomy/constellations/html.html.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 7

EO C340.05 – SIMULATE LIFE IN SPACE

Total Time:	90 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

A practical activity was chosen for TP 1 as it is an interactive way to allow cadets to experience some aspects of life in space. This activity contributes to the development of knowledge of life in space in a fun and challenging setting.

An in-class activity was chosen for TPs 2 and 3 as it is an interactive way to provoke thought and simulate some of the challenges of living in space.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson, the cadet shall have experienced simulated aspects of life in space.

IMPORTANCE

It is important for cadets to realize the challenges of living in a space environment in order to understand the Canadian Space Program. A space environment requires many considerations for the human body to exist comfortably including eating, washing, and working.

Teaching Point 1 | **Explain the Medical Effects of Weightlessness**

Time: 35 min | Method: Practical Activity

MEDICAL EFFECTS OF WEIGHTLESSNESS

On Earth, gravity pulls everything down. Thus, the lower torso and legs carry the weight of the body. In space, because of zero gravity, astronauts float and the legs are not used to support the body.

In space, the lower back and leg muscles are affected the same way as muscles that have been in a cast for a while. Muscles become flabby and lose tone and mass and the astronaut experiences “bird leg syndrome”. “Bird leg syndrome”, called muscular atrophy, makes the limbs thinner. The bones also become weaker because of the loss of minerals like calcium, potassium, and sodium.

The weightlessness of space also affects the cardiovascular system. On Earth, because of gravity, blood naturally pools in the legs, forcing the heart to pump against gravity to supply enough blood to the brain. In space, the heart acts the same as it would on Earth. However, because there is no gravity, the blood rushes to the torso and head. In space the astronaut experiences “puffy face syndrome”. The veins in the neck and face stand out more, and the eyes become red and swollen.

Astronauts try to lessen “puffy face” and “bird leg” syndromes by exercising as often as possible. Astronauts must exercise at least two hours every day to keep their muscles healthy. Astronauts use exercise machines to work both the lower and the upper body muscles. They use a series of straps and restraints to remain secure against the exercise equipment.

ACTIVITY

Time: 25 min

OBJECTIVE

The objective of this activity is to have the cadets simulate exercises that astronauts must perform to maintain bone density and muscle mass when living in a space environment.

RESOURCES

N/A.

ACTIVITY LAYOUT

N/A.

ACTIVITY INSTRUCTIONS

1. Have the cadets stretch for two minutes.
2. Have the cadets alternate between running on the spot and jumping jacks for eight minutes.
3. Have the cadets stretch for two minutes.
4. Have the cadets brainstorm and design exercises that will allow astronauts to keep a set of muscle groups fit in a weightless environment.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. What do astronauts use to exercise?

Q2. What happens to an astronaut in zero gravity?

Q3. How is the cardiovascular system affected in space?

ANTICIPATED ANSWERS

A1. Astronauts use exercise machines to work both the lower and the upper body muscles.

A2. Astronauts float and their legs are not used to support the body.

A3. Due to the lack of gravity the blood rushes to the torso and head.

Teaching Point 2	**Explain the Challenges of Living in Space**
Time: 30 min	Method: In-Class Activity

CHALLENGES OF LIVING IN SPACE

Washing Hands With Rinseless Soap

In space, astronauts cannot wash with water, as water is very difficult to contain in a zero gravity environment. If water drops were left floating in the space vehicle, they could cause serious problems with the equipment. Astronauts use rinseless soap during space missions to clean themselves. Rinseless soap applies easily, the same way as regular soap or hair shampoo, and does not require water to be effective. The alcohol in the rinseless soap kills bacteria.

Sampling Space Food

There are many factors to consider when astronauts live in a space environment and one of these is food. The preparation of the food itself requires special considerations. Storage and transport require the product to be lightweight and have a long shelf life without refrigeration. Weight is critical during a space mission due to transport cost and efficiency. Some methods of food preparation and storage include freeze-drying, retort packing at 125 degrees Celsius, vacuum packing, and dehydrating. Preservation of taste and texture can be difficult with some of these methods. An example of space food is freeze-dried ice cream or strawberries.

Have the cadets feel how light the package of space freeze-dried ice cream or strawberries are by allowing them to hold the wrapped product.

Some dehydrated foods require rehydration, such as macaroni and cheese or spaghetti. The water is kept contained during the transfer from reservoir to food package to avoid loss. An oven is provided in the space shuttle and the space station to heat foods to the proper temperature.

Condiments such as ketchup, mustard, and mayonnaise are provided. Salt and pepper are available, but only in a liquid form, because astronauts cannot sprinkle salt and pepper on their food. The salt and pepper would simply float away. The particles could clog air vents, contaminate equipment or enter an astronaut's eyes, mouth, or nose.

Astronauts eat three meals a day – breakfast, lunch and dinner. Nutritionists ensure the food astronauts eat provides a balanced supply of vitamins and minerals. Caloric requirements differ for different astronauts. For instance, a small astronaut weighing approximately 54 kg would require only about 1900 calories a day, while a large astronaut weighing 100 kg would require about 3200 calories a day.

There are many foods an astronaut can choose from, such as:

- fruits,
- nuts,
- peanut butter,
- chicken,
- beef,
- seafood,
- candy, and
- brownies.

Possible drinks include:

- coffee,
- tea,
- orange juice,
- fruit punches, and
- lemonade.

As on earth, space food comes in packages that must be disposed of. Astronauts must dispose of the packages in a trash compactor inside the space shuttle when they are finished eating. Some packaging actually prevents food from floating away. Food packages are designed to be flexible, easy to use and to maximize space when being stowed or disposed of.

ACTIVITY

Time: 20 min

OBJECTIVE

The objective of this activity is to have the cadets simulate how astronauts wash and eat in space.

RESOURCES

- Freeze-dried strawberries,
- Other freeze-dried fruit as available,
- Freeze-dried ice cream, and
- Rinseless soap.

ACTIVITY LAYOUT

N/A.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into groups of three.
2. Distribute rinseless soap to each group of cadets.
3. Have the cadets wash their hands.
4. Distribute a package of freeze-dried ice cream and strawberries to each group of cadets.
5. Have the cadets taste the freeze-dried ice cream and strawberries.

SAFETY

- Warn cadets and staff that are lactose intolerant that the ice cream contains milk products.
- Warn cadets and staff with an allergy to strawberries that the freeze-dried strawberries are real strawberries.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. Why are dehydrated foods used by astronauts for some of their meals?

Q2. What do astronauts use to wash their hands and hair?

Q3. Why would salt and pepper be a problem in a space environment?

ANTICIPATED ANSWERS

A1. Dehydrating food is used to reduces weight and increases shelf life.

A2. They use rinseless soap and shampoo.

A3. The grains of salt or pepper could clog air vents, contaminate equipment or enter an astronaut's eyes, mouth, or nose.

Teaching Point 3 — **Have the Cadets Simulate Working in Space by Installing a Nut on a Bolt Wearing Two Pairs of Thick Work Gloves**

Time: 20 min — Method: In-Class Activity

Working in zero gravity is a challenge. Often, the only resistance felt by astronauts is the spacesuit itself. In weightless space, any movement in any direction encounters Newton's Third Law and causes an equal force in the opposite direction. For example, when turning a bolt, the force applied in any direction results in an equal force in the opposite direction. Astronauts must attach themselves to, or hold on to, any object to work on it so that they can control the opposite reactive effect.

> Newton's Third Law: for every action there is an equal and opposite reaction.

Spacesuits introduce constraints on movement because they are bulky and, being pressurized, they are stiff. The pressure in an astronaut's spacesuit is 4.3 pounds per square inch (psi). That is less than one-third of the pressure of Earth's atmosphere at sea level (14.7 psi). The air pressure outside an airplane flying at 35 000 feet is near 4.3 psi. It is also about the same as the extra pressure that keeps a football inflated, and like a football, the suit is hard to bend.

Pressure is especially noticeable when wearing gloves. Spacesuit gloves are designed so that there is little pressure when the hand is at rest, but resistance can be felt when the hand is open. This makes manipulating objects difficult when working in the spacesuit.

Tools used in a space environment must be two to three times larger than normal because the gloves are bulky and make manipulating the regular-sized tools difficult. In space, it becomes difficult to do tasks that would be easy to do on Earth. Small details like threading nuts onto bolts require more effort and, worse, dropped objects can be hazardous as they continuously float around and may damage other instruments, controls, or surfaces.

ACTIVITY

Time: 15 min

OBJECTIVE

The objective of this activity is to have the cadets simulate what astronauts do to manipulate objects in a space environment.

RESOURCES

- Work gloves, and
- 1/2-inch National Coarse nuts and bolts.

ACTIVITY LAYOUT

N/A.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into groups of six.
2. Give each group of cadets two pair of gloves and a bolt and a nut.
3. Have one cadet from each group put on two pairs of work gloves and try to pick up the bolt.
4. Put the nut in the cadets' gloved hand and ask the cadet to put the nut on the bolt.
5. Have each cadet perform Steps 3. and 4.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. What are some of the constraints of the spacesuit?

Q2. What law of motion applies to moving in space?

Q3. Why are tools used in space two to three times larger than tools used on Earth?

ANTICIPATED ANSWERS

A1. A spacesuit is suit is stiff because it is pressurized and it is bulky.

A2. Newton's Third Law of motion: for every action there is an equal and opposite reaction.

A3. Spacesuit gloves are stiff and bulky, which restricts the ability to manipulate smaller objects.

END OF LESSON CONFIRMATION

The cadets' participation in all the activities will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Astronauts living in a space environment face many challenges, even in simple things such as washing and eating. With careful planning and consideration of these challenges, life in space can be comfortable and fun.

INSTRUCTOR NOTES/REMARKS

N/A.

REFERENCES

C3-183 (ISBN 978-0-75662-227-5) Graham, I. (2006). *DK Online, Space Travel*. New York, NY: DK Publishing, Inc.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 8

EO C340.06 – LAUNCH A WATER ROCKET

Total Time:	90 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Construct a launching pad as shown at Annex W.

Prepare a string guidance system as shown at Annex X.

Photocopy Annex Y for each cadet.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

A practical activity was chosen for TPs 1 and 2 as it is an interactive way to introduce cadets to water rockets. This activity contributes to the understanding of rocketry in a fun and challenging setting.

A group discussion was chosen for TP 3 as it allows the cadets to interact with their peers and share their knowledge, experiences, opinions, and feelings about water rockets.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet, as a member of a group, shall have constructed and launched a water rocket.

IMPORTANCE

It is important for cadets to launch a water rocket so that they can experience the difference that a higher exhaust pressure makes in rocket flight, compared with using an effervescing tablet for power as was done in EO M140.01 (Build and Launch a Model Rocket, A-CR-CCP-801/PF-001, Chapter 13, Section 1).

Teaching Point 1 **Supervise the Cadets constructing a Water Rocket**

Time: 20 min Method: Practical Activity

Supervise the cadets as they construct a water rocket, to include:

1. fuselage,
2. stabilizing fins,
3. nose cone,
4. centre of gravity trimming, and
5. decorations.

ACTIVITY

OBJECTIVE

The object of this activity is to have the cadets construct a water rocket, which will fly under its own self-contained power.

RESOURCES

- One-litre plastic pop bottles with caps removed,
- Construction paper,
- Scissors,
- Glue,
- Putty or modelling clay,
- Packing tape, and
- Instructions for constructing a water rocket.

ACTIVITY LAYOUT

Cadets shall be organized in groups of no more than four, working together at one table, with all the resources required to build a water rocket.

ACTIVITY INSTRUCTIONS

1. Give each cadet a copy of Annex Y.
2. Explain the instructions located at Annex Y.
3. Each group will construct a water rocket in the manner depicted in Figure 15Y-1.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 1

The cadets' participation in the activity will serve as the confirmation of this TP.

Teaching Point 2	**Supervise the Cadets Launching a Water Rocket**
Time: 50 min	Method: Practical Activity

ACTIVITY

OBJECTIVE

The objective of this activity is to have each group of cadets launch a water rocket constructed in TP 1 and experimentally determine its flight characteristics.

RESOURCES

- Water rockets constructed in TP 1,
- Air pump with pressure gauge,
- Launch pad,
- Drinking straws,
- Packing tape,
- 3-mm string, and
- Safety glasses.

ACTIVITY LAYOUT

1. The CO shall select an outdoor area with controlled access for this training, at least 10 m by 20 m.
2. The string guidance system shall be secured to a suitable tower and the launch pad.
3. Place the launch pad in the centre of the launch area.
4. Anchor the launch pad securely in place.

ACTIVITY INSTRUCTIONS

1. Have one group of cadets place their water rocket, quarter filled with water, on the launch pad.
2. Ensure other cadets stand back 5 m; if necessary, rope off the launch site.
3. After the water rocket is attached to the launcher, have one cadet pump air into the rocket to more than 344 kPa (50 psi) pressure.
4. When pressurization is complete, all cadets shall stand behind the launch control officer.
5. Before conducting the countdown, ensure that the guidance system area is clear.
6. Have one cadet launch the water rocket by pulling the launch release cord.

7. Repeat this process for each group.
8. When all water rockets have been launched, have the cadets retrieve their water rockets.

SAFETY

- Safety glasses must be worn by all cadets and staff during this activity.
- In case of a misfire, the instructor shall ensure that no one approaches the launch pad until the instructor has removed the misfired water rocket.

CONFIRMATION OF TEACHING POINT 2

The cadets' participation in launching a water rocket will serve as the confirmation of this TP.

Teaching Point 3	**Conduct an Activity Debriefing**
Time: 10 min	Method: Group Discussion

BACKGROUND KNOWLEDGE

The point of the group discussion is to draw the following information from the group using the tips for answering/facilitating discussion and the suggested questions provided.

Characteristics of the Successful Launches

The forces acting upon the cadets' water rockets in flight are those acting upon any aircraft:

- gravity,
- thrust,
- drag, and
- lift, which is minimal in this case unless the water rocket is provided with an airfoil.

Drag and lift are atmospheric forces that result from air coming in contact with the body of the water rocket.

There are many propellants used in rocketry, resulting in a variety of exhaust pressures and velocities. The greater the exhaust pressure, the higher the exhaust velocity. The rocket's power is increased as exhaust velocity of the propellant increases.

When launching a water rocket, there is a difference that a higher exhaust pressure makes in rocket flight, compared with using an effervescing tablet for power as was done in EO M140.01 (Build and Launch a Model Rocket, A-CR-CCP-801/PF-001, Chapter 13, Section 1). Since the water rocket launched in this lesson is heavier when filled with propellant, it may start slower, but the greater mass of the propellant may allow it to attain even greater speeds and distances.

Rocket Behaviour Under Newton's Laws

First Law. Every object in motion tends to remain in motion until an external force is applied to it.

Second Law. The direction of acceleration is the same as the direction of the force. Therefore, since the reactive force pushes upwards against the bottle as the water is directed downwards, the force acting upon the water rocket is also directed upwards.

Third Law. For every action there is an equal and opposite reaction. Therefore, matter such as water particles escaping outward from the rear nozzle will push upon the body of the water rocket.

GROUP DISCUSSION

TIPS FOR ANSWERING/FACILITATING DISCUSSION

- Establish ground rules for discussion, eg, everyone should listen respectfully; don't interrupt; only one person speaks at a time; no one's ideas should be made fun of; you can disagree with ideas but not with the person; try to understand others as much as you hope they understand you; etc.
- Sit the group in a circle, making sure all cadets can be seen by everyone else.
- Ask questions that will provoke thought; in other words avoid questions with yes or no answers.
- Manage time by ensuring the cadets stay on topic.
- Listen and respond in a way that indicates you have heard and understood the cadet. This can be done by paraphrasing their ideas.
- Give the cadets time to respond to your questions.
- Ensure every cadet has an opportunity to participate. One option is to go around the group and have each cadet answer the question with a short answer. Cadets must also have the option to pass if they wish.
- Additional questions should be prepared ahead of time.

SUGGESTED QUESTIONS

Q1. Which rocket was heavier? The water rocket or the film canister rocket in Proficiency Level One?

Q2. Which rocket flew further?

Q3. Which rocket flew faster?

Q4. How might increased pressure or an increased volume of propellant affect the rocket?

Other questions and answers will develop throughout the group discussion. The group discussion should not be limited to only those suggested.

Reinforce those answers given and comments made during the group discussion, ensuring the teaching point has been covered.

CONFIRMATION OF TEACHING POINT 3

The cadets' participation in the group discussion will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' participation in launching the water rocket and in the group discussion will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

There are many propellants used in rocketry, resulting in a variety of exhaust pressures and velocities. The greater the exhaust pressure, the higher the exhaust velocity. The rocket's power is increased as exhaust velocity of the propellant increases.

INSTRUCTOR NOTES/REMARKS

Prior to this lesson, instructors shall prepare a launching platform and guidance system as shown at Annexes W and X or reference C3-016.

The launching pad should be saved for future training.

Each group shall be allowed a number of attempts to achieve a successful launch.

If a suitable location for this launching water rockets is not available at the squadron's LHQ, that part of the lesson can be carried out as part of a field exercise.

REFERENCES

C3-016 EG-2003-01-108-HQ NASA. (2003). *Rockets: A Teacher's Guide With Activities in Science, Mathematics, and Technology*. Washington, DC: NASA.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 9

EO C340.07 – IDENTIFY GLOBAL POSITION SYSTEM (GPS) COMPONENTS

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Retrieve current information from reference C3-243 and update the lesson as required.

Create slides of figures located at Annexes Z to AB.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to orient the cadets to GPS components, to generate interest, and emphasize the teaching points.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall be have identified GPS components.

IMPORTANCE

It is important for cadets to be able to identify GPS components so that they will clearly understand the operation and capabilities of GPS when it is used in the field or in an aircraft.

Teaching Point 1 | **Explain How the GPS Operates**

Time: 25 min | Method: Interactive Lecture

In 1870, an American named Edward Everett Hale suggested a system of four satellites be placed in a circumpolar orbit to provide a global positioning service. This idea was published as a story called *The Brick Moon* in a series of installments in Boston's Atlantic Monthly magazine in 1870 and 1871.

The complete *The Brick Moon* is available at the University of Virginia Library at website http://etext.virginia.edu/toc/modeng/public/HalBric.html.

THE THREE COMPONENTS OF GPS

There are multiple positioning systems that use satellites, including the Russian military's Glonass system and the US military's Navstar system. This lesson describes Navstar, but both systems share the same principles in data transmission and positioning methods, though other details such as orbits differ. Other systems existing or planned include those belonging to Japan and the European Union.

Today's GPS represents a considerable advance from Hale's brick moon idea. It has three components:

- orbiting satellites,
- earthbound control stations, and
- receivers that can be anywhere – earthbound, flying or orbiting.

Satellites

The space segment of GPS consists of 24 operational satellites in six orbital planes (four satellites in each plane). The spacing of the satellites are arranged so that a minimum of five satellites are in view from every point on the globe at any time. The satellites orbit at an altitude of 20 200 km. That altitude, clear of the atmosphere, means that satellites will orbit according to very simple mathematics. Although all the satellites are at the same altitude and their six orbits do cross, the satellites do not collide because they are carefully synchronized.

Control Stations

The control segment of GPS consists of five monitor stations and three ground antennas located around the world. A Master Control Station (MCS) is located at Schriever Air Force Base (AFB) in Colorado. The monitor stations passively track all satellites, gathering information to be processed at the MCS to determine satellite orbits and to update each satellite's navigation message. Updated information is transmitted to each satellite via the ground antennas.

Receivers

The user segment of GPS consists of antennas and receiver-processors that provide positioning, velocity, and precise timing to the user. There is a wide variety of receivers.

Individuals may purchase GPS handsets that are available through commercial retailers. Equipped with these GPS receivers, users can accurately locate where they are and easily navigate to where they want to go, whether walking, driving, flying, or boating. GPS receivers have become a mainstay of transportation systems worldwide, providing navigation for aviation, ground, and maritime operations. Disaster relief and emergency services depend upon GPS receivers for location and timing capabilities in their life-saving missions. Everyday activities such as banking, mobile phone operations, and even the control of power grids, are facilitated by the accurate timing provided by GPS receivers. Farmers, surveyors, geologists and countless others perform their work more efficiently, safely, economically, and accurately using the free and open signals of the GPS satellites.

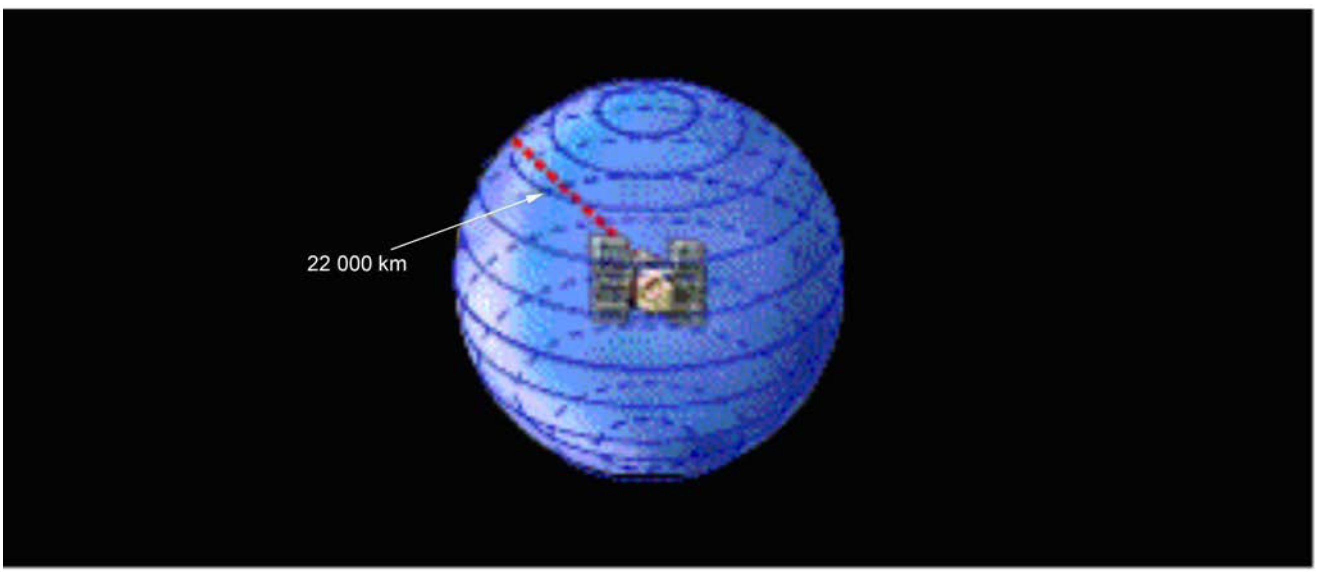
TRILATERATION FROM THREE SATELLITES

Since angles are not used in the computation, trilateration is a more accurate term than the popular term triangulation. However, the term triangulation is used by most people. For the purposes of this lesson, the two terms are interchangeable.

The principle behind GPS is the use of satellites in space as reference points for describing locations on earth. By very accurately measuring distance from three satellites a position can be trilaterated anywhere on or over the earth.

Show the cadets Figure 15Z-1.

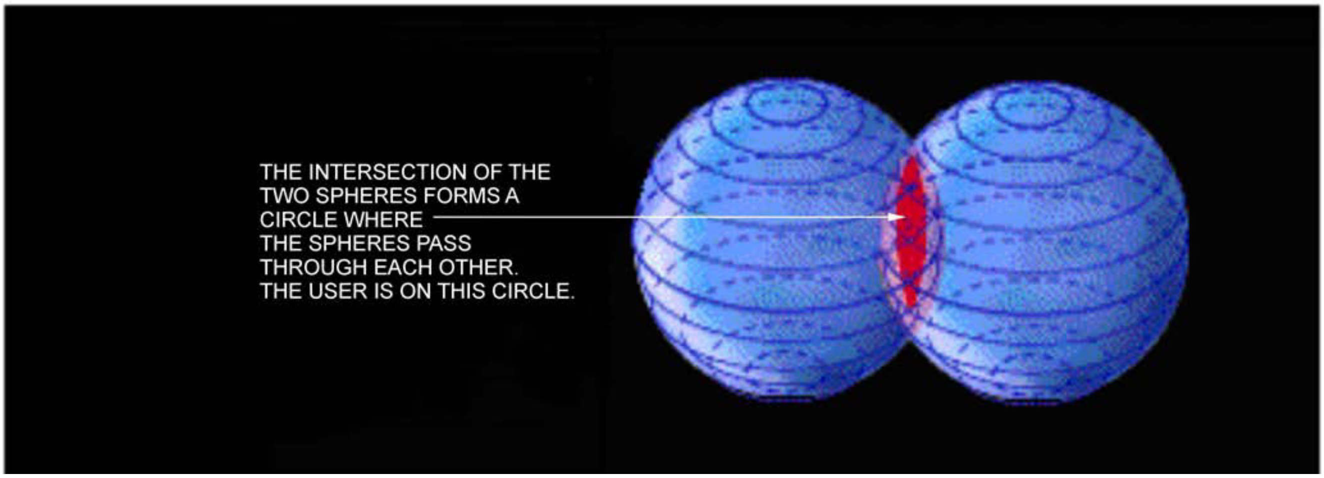
A single measurement of distance from a satellite might find the distance to be 22 000 km. Knowing that this location is 22 000 km from a particular satellite narrows down all the possible locations one could be, to the surface of a sphere that is centered on this satellite and has a radius of 22 000 km.



"GPS Tutorial", Trimple Navigation Limited, 2008, How GPS Works? Copyright 2008 by Trimple Navigation Limited. Retrieved April 11, 2008, from http://www.trimble.com/gps/howgps-triangulating.shtml

Figure 15-9-1 First Trilateration

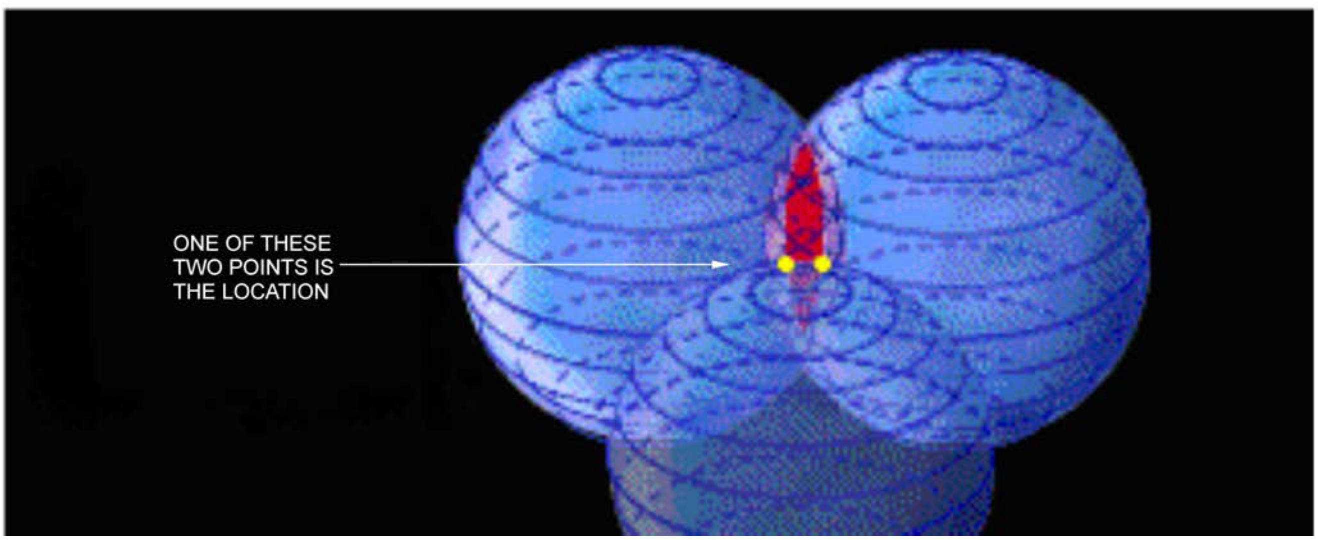
If a second measurement shows this same location to be 23 000 km from a second satellite, it is not only on the first sphere but also on a sphere 23 000 km from the second satellite. The location must be somewhere on the circle where these two spheres intersect.



"GPS Tutorial", Trimple Navigation Limited, 2008, How GPS Works? Copyright 2008 by Trimple Navigation Limited. Retrieved April 11, 2008, from http://www.trimble.com/gps/howgps-triangulating.shtml

Figure 15-9-2 Second Trilateration

If a third measurement shows the same location to be 24 000 km from a third satellite, it is not only on the first sphere and the second sphere, but also on another sphere that is 24 000 km from the third satellite. This narrows the location down to the two points where the 24 000 km sphere intersects with the circle formed by the intersection of the first two spheres.



"GPS Tutorial", Trimple Navigation Limited, 2008, How GPS Works? Copyright 2008 by Trimple Navigation Limited. Retrieved April 11, 2008, from http://www.trimble.com/gps/howgps-triangulating.shtml

Figure 15-9-3 Third Trilateration

From three satellites a location can be determined to be one of just two points in space – only one of which will usually be on the surface of the earth or at the correct altitude above it. To decide which of those two points is the true location, a fourth trilateration measurement is necessary. However, one of the two points may be a ridiculous answer (either too far from Earth or moving at an impossible velocity) and so can be rejected without further measurement.

TIMING RADIO SIGNALS

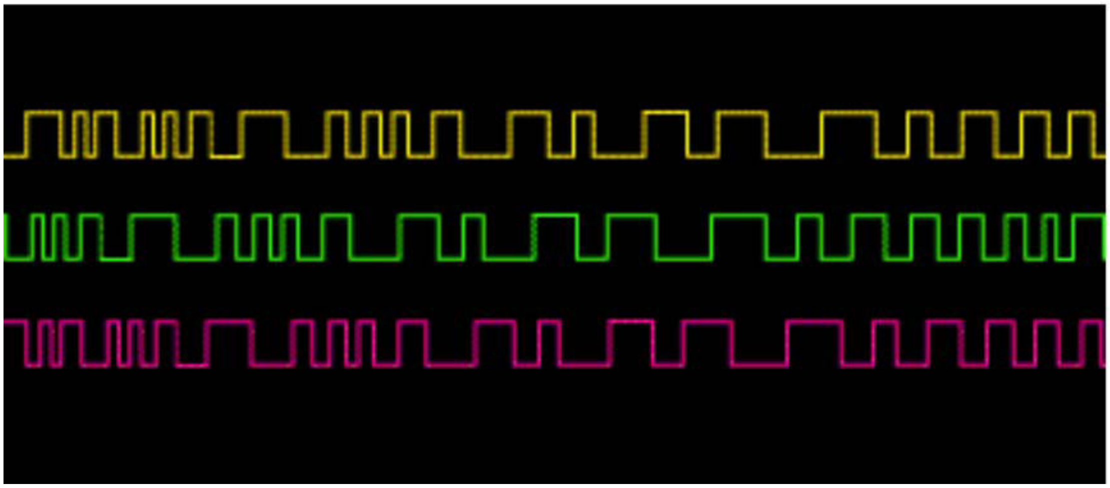
Show the cadets Figures 15AA-1 and 15AA-2.

Distance to a satellite is determined by measuring how long a radio signal takes to travel from that satellite to the user's receiver. By comparing how long it takes the satellite's coded signal to arrive at the user's receiver, compared to the receiver's internal clock, the travel time can be determined. Finally, comparing that measured travel time to the speed of light gives the distance.

"GPS Tutorial", Trimple Navigation Limited, 2008, How GPS Works? Copyright 2008 by Trimple Navigation Limited. Retrieved April 11, 2008, from http://www.trimble.com/gps/howgps-triangulating.shtml

Figure 15-9-4 Travelling Down

Each GPS satellite transmits a coded waveform radio signal (somewhat like those shown in Figure 15-9-5). Notice that the individual pulses, or waves, are of different shapes. This allows the receiver to recognize individual pulses. GPS receivers generate waveforms that are identical to those transmitted by the satellite, for the receiver's internal use. To calculate the travel time of the radio signal from the GPS satellite, the GPS receiver measures how much time the received satellite waveform is behind its own identical internal waveform. It does this by comparing synchronization of its own internal waveforms with that of the waveforms received from each satellite.

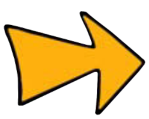


"GPS Tutorial", Trimple Navigation Limited, 2008, How GPS Works? Copyright 2008 by Trimple Navigation Limited. Retrieved April 11, 2008, from http://www.trimble.com/gps/howgps-triangulating.shtml

Figure 15-9-5 Coded Signals

Of course, this system requires perfect synchronization. All three of the GPS components – satellites, control stations and receivers – have excellent timekeeping ability.

Show the cadets The Challenge of Timing slide located at Annex AA.



Timing is tricky.

Precise clocks are needed to measure travel time.

The travel time from a satellite directly overhead is about 0.06 seconds.

The time required to synchronize the receiver's internal coded pulses with the satellite's coded pulses is equal to the travel time.

Distance to the satellite is equal to travel time multiplied by the speed of light.

As well as extremely accurate internal timing, the GPS receiver must have one last critical piece of information – the exact time on the satellite's clock. The speed of light is so great, and the travel time of the radio signal is so short, that the clock in the GPS satellite and the clock in the GPS receiver must be synchronized perfectly. This requirement, given the degree of accuracy necessary, is a formidable challenge. The method that was used to accomplish this feat involves high-speed computer processing combined with data from a fourth GPS satellite.

ACTIVITY

Time: 10 min

OBJECTIVE

The objective of this activity is to have the cadets experience the precision of GPS.

RESOURCES

- One hand-held GPS receiver, and
- Paper and pencil/pen.

ACTIVITY LAYOUT

Training area suitable for drill.

ACTIVITY INSTRUCTIONS

1. Designate a right marker.
2. Face the right marker south.
3. Have the remaining cadets fall in single file and perform a right dress.
4. Give the marker a hand-held GPS receiver.
5. Have the marker call out the coordinates shown on the GPS receiver and pass the receiver to the next cadet.
6. Write down the marker’s coordinates.
7. Repeat Steps 5. and 6. for each cadet in the file.
8. List the coordinates on a whiteboard or flip chart.
9. Have the cadets examine the listed coordinates to determine:
   (a) How many seconds did the longitude change from one end of the file to the other?
   (b) How many seconds did the longitude change per cadet, on average?

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. What are the three components of the GPS?

Q2. How many satellites does it take to mathematically establish a location?

Q3. How is distance to a single satellite determined?

ANTICIPATED ANSWERS

A1. Satellites, control stations and receivers.

A2. Four.

A3. By measuring how long a radio signal takes to travel from that satellite to the user’s receiver.

Teaching Point 2	Describe the Constellation of 24 GPS Satellites
Time: 5 min	Method: Interactive Lecture

THE CONSTELLATION OF 24 GPS SATELLITES

There are more than 24 GPS satellites in orbit. Satellites are constantly being moved or replaced, either temporarily or permanently. However, at any given time, 24 of the satellites are in service.

ORBIT CHARACTERISTICS

The 24 GPS satellites' circular 20 200 km orbits are inclined 55 degrees with respect to Earth's equator. The satellites complete an orbit every 12 hours and rise 4 minutes earlier each day, which adds up to 24 hours in a year. This is necessary because Earth orbits the Sun once a year and, to keep accurate time, the satellite must not change orbital position in the course of a year, relative to the stars.

STATION-KEEPING MANOEUVRES

Once per year each satellite requires a station-keeping manoeuvre, also referred to as repositioning, to move the satellite back to its original orbital position. The satellites have a tendency to drift from their assigned orbital positions. One reason for this is the gravitational pull of the Earth, Moon and Sun. These manoeuvres require, on average, 12 hours of unusable time for each satellite.

ON-BOARD GPS EQUIPMENT

In addition to the radio transmitters required to communicate with the user's GPS receivers on at least two separate frequencies, a GPS satellite will usually also have:

- accurate clocks and computers for generation of coded timing signals,
- radio receivers and transmitters to communicate with the earth-based MCS,
- antennas for the radio equipment,
- rocket thrusters for orbital location and attitude adjustments,
- propellant tanks for the thrusters engines,
- computers for controlling the thrusters engines,
- solar panels to power on-board electrical equipment, and
- batteries for storing the electrical power.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. How many GPS satellites are in orbit?

Q2. What is the shape of a GPS satellite orbit?

Q3. What is a station-keeping manoeuvre for?

ANTICIPATED ANSWERS

A1. More than 24.

A2. Circular.

A3. To move the satellite back to its original orbital position after it drifts.

Teaching Point 3	**Describe the Network of Earth-Based Control Stations**
Time: 5 min	Method: Interactive Lecture

THE NETWORK OF EARTH-BASED CONTROL STATIONS

The GPS satellite orbits are exact and the satellites are constantly monitored. Radar is used to check each satellite's exact altitude, position and speed. Errors are called "ephemeris errors" because they affect the satellite's orbit or "ephemeris." These errors are caused by gravitational pulls from the moon and sun and by the pressure of solar radiation on the satellites. The errors are usually very slight but they must be corrected to achieve the required accuracy.

Show the cadets Figure 15AA-1.

The control component of GPS consists of five monitor stations, three ground antennas and one MCS. The monitor stations passively track all satellites in view, accumulating ranging data. This information is passed to the MCS where it is processed to determine satellite orbits and to update each satellite's navigation message. Updated information is transmitted to each satellite via the ground antennas.

FIVE MONITOR STATIONS

The five monitor stations are located at:

- Hawaii, in the eastern Pacific Ocean,
- Kwajalein, in the western Pacific Ocean's Marshall Islands east of Hawaii,
- Ascension Island, in the south Atlantic Ocean,
- Diego Garcia, in the Indian Ocean, and
- Colorado Springs, in central USA.

THREE GROUND ANTENNAS

The three ground antennas are at Ascension Island, Diego Garcia and Kwajalein. These are necessary for transmitting control signals from the MCS to the satellites.

THE MASTER CONTROL STATION (MCS)

The MCS is located at the US Schriever AFB in Colorado. Only the MCS communicates with the GPS satellites, using the three ground antennas at Ascension Island, Diego Garcia and Kwajalein.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. In which US state is the MCS located?

Q2. What do monitor stations do?

Q3. Name the location of one ground antenna.

ANTICIPATED ANSWERS

A1. Colorado.

A2. The monitor stations passively track all satellites in view, accumulating ranging data.

A3. Ascension Island, Diego Garcia, or Kwajalein.

Teaching Point 4	**Describe the User Receivers**
Time: 15 min	Method: Interactive Lecture

GPS USER RECEIVERS

By obtaining a GPS receiver, users automatically get the use of the space component and the control components of the system. GPS receivers are designed and built to interact correctly with the space and control components of GPS. All GPS receivers have an almanac programmed into their computers that tells them where in the sky each satellite is, moment by moment. It only remains to measure how far away the satellites are and then the receiver can calculate its own location.

TIME CORRECTION FOR THE USER RECEIVER

As well as extremely accurate timing, the GPS receiver must have one critical piece of information to measure the distance to a satellite – the exact time on the satellite's clock. The speed of light is so great, and the travel time of the radio signal is so short, that the clock in the GPS satellite and the clock in the GPS receiver must be synchronized perfectly. This requirement, and the degree of accuracy necessary, is a formidable challenge. The method that was used to accomplish this feat involves high-speed computer processing combined with additional data from a fourth GPS satellite.

If the GPS receiver's clocks and the GPS satellite's clocks are perfectly synchronized to universal time, then all the satellite ranges would intersect at a single point (which is the position of the receiver). With imperfect clocks such as those found in the real world, a measurement taken from a fourth GPS satellite, done as a crosscheck, will not intersect with the first three. Since any offset from universal time will affect all measurements equally, the GPS receiver's computer searches for a single correction factor. The correction factor that the receiver must find is the one that it can subtract from all its timing measurements to cause them to intersect at a single point – the location of the receiver. This solution is accomplished by high-speed computing. Once the correction factor is found, the receiver will know not only its own location, but also the precise time on all the satellite's clocks.

USER RECEIVER APPLICATIONS

Many uses for GPS have been found, but there are five main categories: locating, navigating, tracking, mapping, and timing.

Locating

The first and most obvious application of GPS receivers is the determination of a position or location. A GPS receiver is the first positioning system to offer highly precise location data for any point on the planet, in any weather. That alone would be enough to qualify it as an important tool, but GPS accuracy makes it useful in special applications.

Besides just identifying a location, an exact reference locator is sometimes needed for extremely precise scientific work. When a GPS receiver was used to measure Mount Everest, the data collected improved past work, but also revealed that the mountain is getting taller.

Navigating

By providing more precise navigation tools and accurate landing systems, a GPS receiver not only makes flying safer, but also more efficient. With precise point-to-point navigation, a GPS receiver saves fuel and extends an aircraft's range by ensuring pilots do not stray from the most direct routes to their destinations.

Tracking

Tracking is the process of monitoring something as it moves from one location to another. Commerce relies on fleets of vehicles to deliver goods and services either across a city or across a nation. Effective fleet management has important implications, such as telling a customer when a package will arrive, spacing buses for the best-scheduled service, directing the nearest ambulance to an accident, or helping tankers avoid hazards.

A GPS receiver used in conjunction with communication links and computers can provide the backbone for systems tailored to applications in agriculture, mass transit, urban delivery, public safety, and vessel and vehicle tracking. So it is no surprise that police, ambulance, and fire departments have adopted GPS to pinpoint both the location of the emergency and the location of the nearest response vehicle on a computer map. With this clear visual picture of the situation, dispatchers can react immediately and confidently.

Mapping

Using a GPS receiver to survey and map precisely saves time and money. A GPS receiver makes it possible for a single surveyor to accomplish in a day what used to take weeks with an entire team. Even at that faster speed surveyors can do their work with a higher level of accuracy than was possible without a GPS receiver.

Mapping is the art and science of using a GPS receiver to locate items, then create maps and models of everything in the world: mountains, rivers, forests and other landforms, roads, routes, and city streets as well as precious minerals and resources.

The Longitude of Greenwich describes some of the problems that prevent GPS technology from meshing perfectly with the standard maps that are used throughout the world. Even Britain's Royal Observatory was stumped. Details of this Prime Meridian location puzzle can be found at the Royal Observatory website http://www.nmm.ac.uk/server/show/conWebDoc.416.

The accuracy of GPS receivers can reveal serious problems with standard mapping methods and that can cause problems that are not easy to solve. One case involves the Prime Meridian.

The problem: Why does a GPS receiver operating on the zero meridian at Greenwich indicate a longitude differing by about 100 m from zero?

Show the cadets Figure 15AB-1.

The Prime Meridian was defined, in classical navigation and map-making, to be the line of longitude passing through Greenwich in England. All other lines of longitude were measured relative to this meridian, which was originally established to be 0 degrees. That was how the International Date Line came to be on the opposite side of the earth, at 180 degrees longitude in the middle of the Pacific Ocean.

However, longitudes, latitudes and heights in the system that the GPS uses are all measured relative to a theoretical spheroid that best fits mean sea level over the whole globe. While this represents a level of accuracy that was unavailable to previous generations of cartographers (map-makers), the difference of 100 m in the location of the Prime Meridian obviously poses a problem for today's surveyors and cartographers.

When using a GPS receiver in conjunction with standard maps, it is possible to find significant conflicts between the two systems. The information from a GPS receiver will be precisely accurate, but the information it provides can be confusing when used with a standard map.

Timing

Although a GPS receiver is well known for navigation, tracking, and mapping, it is also used to disseminate precise time, time intervals, and frequency. Time is a valuable resource and knowing the exact time is more valuable still. Knowing that a group of timed events is perfectly synchronized is often very important. A GPS receiver makes synchronization and coordination easy and reliable.

There are three fundamental ways time is used. As a universal marker, time tells us when things happened or when they will happen. As a way to synchronize people, events and other types of signals, time helps keep the world on schedule. As a way to tell how long things last, time provides and accurate, unambiguous sense of duration.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS

Q1. What critical piece of information does a GPS receiver need to find to calculate its position?

Q2. What are the five main categories of GPS applications?

Q3. Why must a GPS receiver always calculate a correction factor for its internal clock?

ANTICIPATED ANSWERS

A1. The exact time on the satellite's clock.

A2. Locating, navigating, tracking, mapping, and timing.

A3. All clocks are imperfect and the GPS must have time that is perfectly synchronized with the GPS satellite.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. What are the three components of the GPS?

Q2. How many GPS satellites are in orbit?

Q3. In which US state is the MCS located?

ANTICIPATED ANSWERS

A1. Satellites, control stations, and receivers.

A2. More than 24.

A3. Colorado.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Few pieces of information are as useful as a clear and precise description of one's location. GPS describes location, trajectory and speed of any object of interest, making GPS service invaluable to transportation, industry and commerce – as well as leisure pursuits.

INSTRUCTOR NOTES/REMARKS

N/A.

REFERENCES

A2-041 B-GL-382-005/PT-001 Canadian Forces. (2006). *Maps, Field Sketching, Compasses and the Global Positioning System*. Ottawa, ON: Department of National Defence.

C3-243 US Naval Observatory. (2008). *USNO GPS Timing Operations*. Retrieved February 10, 2008, from http://tycho.usno.navy.mil/gps.html.

C3-244 Trimble Navigation Limited. (2006). *GPS Tutorial*. Retrieved February 10, 2008, from http://www.trimble.com/gps/index.shtml.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 10

EO C340.08 – DESCRIBE ASPECTS OF THE INTERNATIONAL SPACE STATION (ISS)

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create a slide of Annex AC.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to orient the cadets to aspects of the ISS, to generate interest, and emphasize the teaching points.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have described aspects of the ISS.

IMPORTANCE

It is important for cadets to describe aspects of the ISS in order to understand the scope of international cooperation involved, the size of the project and the mission capability of the ISS.

Teaching Point 1	**Describe the Major Components of the ISS**
Time: 15 min	Method: Interactive Lecture

MAJOR COMPONENTS OF THE ISS

The ISS is a large-scale project which requires international cooperation. Major contributors include the United States through National Aeronautics and Space Administration (NASA); Canada through the Canadian Space Agency (CSA); Britain, France, Germany, and Spain through the European Space Agency (ESA); Italy through the Italian Space Agency; Japan through Tsukuba Space Centre; and Russia through Roscosmos.

Each of these contributors has been responsible for the funding and construction of the major components of the ISS.

Construction of the ISS was started in 1998 and is scheduled to be completed by 2010.

Images of the ISS and its individual modules can be viewed at the NASA website. Each of the modules described here are cylindrical in shape and are connected either to each other or to one of the nodes.

Show slide of Annex AC. If a model is available, it should be used as well.

National Aeronautical and Space Administration, STS-118 Build the Station, Build the Future, NASA (p. 54)

Figure 15-10-1 Space Shuttle *Endeavour* (STS-118) After Undocking From the ISS

Zarya

Zarya (sunrise) was the first module of the ISS to be launched. It was also the first Russian contribution. The module is used primarily for storage, though its original purpose was to provide power, communications and orientation control while waiting for the Zvezda module.

Unity

The Unity Node is a connecting passageway to living and work areas of the ISS. This was the second ISS module and the first US contribution.

Zvezda

The Zvezda Service Module serves as the cornerstone for the first habitable sections of the ISS. The module provided the early living quarters, life support, electrical power distribution, data processing, flight control system and propulsion system. Launched in July 2000, this module has already undergone updates to both hardware and software. This was the second Russian contribution to the ISS.

Harmony

The Harmony Node increases the living and workspace of the ISS by 500 cubic metres. It is a passageway between the three station science facilities (Destiny, Kibo and Columbus), and provides a platform for the Multi-Purpose Logistics Modules, the transfer vehicle, the mating adaptor for the shuttle, and the Canadarm2. This was a US contribution.

Destiny

Destiny is the US laboratory attached to the ISS. Destiny's interior is modular in design so that as mission requirements change, modules can be added or removed. At maximum capacity, Destiny is expected to hold 13 experiments focusing on human life sciences, materials research, Terran observations and commercial applications.

One feature of Destiny which has affected life on earth already is its window. From here, high quality photos and videos of earth can be taken, such as those used for BBC's documentary productions *Blue Planet* and *Planet Earth*.

Multi-Purpose Logistics Modules (MPLMs)

Three MPLMs were constructed by the Italian Space Agency to assist in the transportation of materiel to and from the ISS. The modules are pressurized and are designed to be carried inside the shuttle bay during launch and recovery. Once in space, the shuttle will dock with the ISS and use its Canadarm to transfer the MPLM to a docking port on the ISS. Crew from the ISS will transfer goods to and from the MPLM. Once the transfer is complete the MPLM will return to earth onboard the shuttle.

The three MPLMs are named after famous Italians:

- MPLM Leonardo, named after Leonardo da Vinci;
- MPLM Donato, named after Donato di Niccolo Di Betto Bardi (aka Donatello);
- MPLM Rafaello, named after Rafaello Sanzio (aka Raphael).

Kibo

A Japanese contribution, Kibo (hope) is a scientific research facility. It includes two laboratory facilities, two logistics modules, a Remote Manipulator System, and an Inter-Orbit Communication System. Experiments in Kibo focus on space medicine, biology, Terran observations, material production, biotechnology and communications research.

Columbus

Built in Germany, Columbus is the ESA's largest contribution to the ISS. Columbus is a research laboratory which will expand the research facilities of the ISS. It is attached to the Harmony Node, as well as the Destiny and Kibo research labs. Experiments focus on life sciences, materials sciences, fluid physics, and other research in a weightless environment which cannot be conducted on earth.

Two unique aspects of Columbus include:

- remote access to experiments, allowing researchers on earth to coordinate with the station crew to conduct experiments; and
- the ability to conduct experiments in the vacuum of space at any of the four exterior mounting platforms.

Automated Transfer Vehicles (ATVs)

In 2008, the ESA started construction on the first of at least seven ATVs. The ATV is designed to be an unpiloted cargo carrier, which will supply the ISS with liquid and dry cargo as well as gases. It has a substantially greater cargo capacity than the Russian *Progress* cargo carrier, which currently delivers cargo to the ISS. Its secondary duty is as a garbage scow, collecting garbage from the ISS.

The Mobile Servicing System (MSS)

The MSS is a robotic system that plays a key role in the assembly and maintenance of the ISS. It moves equipment and supplies around the exterior of the station, supports astronauts during extravehicular activity (EVA), and services instruments and modules attached to the ISS.

The MSS is composed of three parts, all contributed by Canada. They are:

- **Canadarm 2.** The next generation of the Canadarm located in the space shuttle, Canadarm 2 has improved agility, increased size and capabilities, and is not fixed to one position.
- **Mobile Base System.** The mobile base system is a work platform, which moves along rails attached to the outside of the ISS. This provides the Canadarm 2 with lateral mobility along the main trusses of the ISS.
- **Special Purpose Dexterous Manipulator (Dextre).** Dextre is a two armed robot, which may be attached to the Canadarm 2. Its purpose is to handle delicate assembly tasks currently conducted by astronauts.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. Which was the first ISS module to be launched?

Q2. Which three modules are research facilities on the ISS?

Q3. What is Canada's contribution to the construction of the ISS?

ANTICIPATED ANSWERS

A1. Zarya.

A2. Destiny, Kibo and Columbus.

A3. The MSS.

Teaching Point 2	**Discuss ISS Missions**
Time: 10 min	Method: Interactive Lecture

ISS MISSIONS

The main role of the ISS is to be a research facility. Once construction of the ISS is complete, scientists from the various contributing space agencies will be able to conduct hundreds of experiments from many fields of study.

Materials International Space Station Experiment (MISSE)

The MISSE will test the durability of hundreds of samples ranging from lubricants to solar cell technologies. The samples are better engineered to withstand the Sun, extreme temperatures and other elements. They will be attached to the exterior of the ISS, taking them outside of the protection of the Earth's atmosphere. By examining how the materials fare in space, researchers will be able to develop new materials for use in spacecraft as well as make materials that can last longer on Earth.

One example of where this research will be used on Earth is in exterior paint. Materials in space are subjected to more ultra-violet radiation (responsible for paint degradation) than materials on Earth. By applying the knowledge gained in these experiments, paint producers can create paint, which will last longer.

Minus Eighty Degrees Celsius Laboratory Freezer for ISS (MELFI)

MELFI is a large freezer onboard the ISS. It uses nitrogen gas (N_2) as the freezing agent. The purpose of MELFI is to store biological and life sciences samples at controlled temperatures. These temperatures range from 10 degrees Celsius to 99 degrees below 0 Celsius. Samples may include blood, urine, or plants.

Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES)

SPHERES are spherical satellites the size of a bowling ball. They will be used inside the ISS to test a set of instructions which will be used by spacecraft performing autonomous rendezvous and docking manoeuvers. Three free-flying SPHERES will perform formation flying inside the cabin of the ISS. Each of these satellites is self-contained with power, propulsion, computers and navigation equipment. The results of this study will be used for satellite servicing, vehicle assembly and determining formations for spacecraft to fly.

Online Viewing of ISS Missions on NASA TV

It is possible to view the ISS missions through online streaming video at the NASA website. Most of the video is archived footage, however live footage is aired during scheduled broadcasts. NASA TV is accessible on the NASA website at http://www.nasa.gov.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. What will researchers be able to do with the data gained from MISSE?

Q2. What will the results of SPHERES be used for?

Q3. Where can one go to view NASA TV?

ANTICIPATED ANSWERS

A1. Researchers will be able to develop new materials for use in spacecraft as well as make materials that can last longer on earth.

A2. The results of this study will be used for satellite servicing, vehicle assembly and determining formations for spacecraft to fly.

A3. NASA TV is accessible on the NASA website at http://www.nasa.gov.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. What are the two Russian contributions to the ISS?

Q2. Which Italian contribution will be used to assist the space shuttle in delivering cargo to the ISS?

Q3. Which two vehicles, other than the space shuttle, are used for transporting goods to and from the ISS?

ANTICIPATED ANSWERS

A1. Zarya and Zvezda modules.

A2. The MPLMs (Leonardo, Donato, and Raffaello).

A3. The Russian *Progress* and the ATVs.

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

The ISS is a major step forward for humanity. Not only does it allow for scientific research of space, but it represents collaboration between the different nations of man. Resources that may otherwise be used in conflict are being used to further humanity's knowledge and abilities.

INSTRUCTOR NOTES/REMARKS

A model of the ISS would make an ideal visual aid for this lesson. Scale models may be purchased through online sources or ordered at the local hobby store.

In lieu of a model, a large poster would make a great visual aid. Images and multimedia are available through online sources, including NASA.

REFERENCES

C3-245 NASA. (2008). *International Space Station*. Retrieved February 10, 2008, from http://www.nasa.gov/mission_pages/station/main/index.html.

C3-246 NASA. (2008). *NASA TV*. Retrieved February 12, 2008, from http://www.nasa.gov/multimedia/nasatv/index.html.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 11

EO C340.10 – IDENTIFY ONLINE STARGAZING PROGRAMS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Visit the SkyView and SKY-MAP.ORG websites and navigate through the various databases presented.

Create slides of Annexes AD and AE.

Photocopy the handout located at Annex AF for each cadet.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to orient the cadets, generate interest, present background material, and clarify online stargazing.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet should be expected to identify two online stargazing programs.

IMPORTANCE

It is important for cadets to identify online stargazing programs because online stargazing supports amateur astronomy. When weather and background light make outdoor viewing impossible, these programs make stargazing possible.

Teaching Point 1 | **Discuss NASA's SkyView**

Time: 5 min | Method: Interactive Lecture

NASA'S SKYVIEW

SkyView is a virtual observatory on the Internet, which generates images of any part of the sky.

SkyView takes observations that other astronomers have made and uses them to create an image of the celestial target of interest. The user must specify which survey or surveys to use.

How to Access SkyView

> Show the cadets Figure 15AD-1.

1. Type the URL http://skyview.gsfc.nasa.gov/ in the address field on the Internet.
2. On the SkyView home page, select the Non-Astronomers page using a blue button found halfway down the page, on the left side of the screen.

> Show the cadets Figure 15AD-2.

3. Choose the SkyView Query Form button. Access an interactive form to select the desired view of the sky. There are, at a minimum, two required parameters:
   (a) the celestial coordinates of the sky to be viewed or the object's name, and
   (b) the database to be accessed for creating the view.

> The celestial coordinate system describes an object's position as right ascension and declination.
>
> **Right Ascension.** This is comparable to longitude on the earth, but measured in hours, minutes and seconds.
>
> **Declination.** This is comparable to latitude on the earth, measured in degrees.

> The easiest way to determine coordinates is to visit SKY-MAP.ORG; details of which are explained in the next TP. If the desired target is known, put it in the SkyView Query Form.

Show the cadets Figure 15AD-3.

NGC 4030, a galaxy in the constellation Virgo, was entered as the target in the text box, the image returned is shown in Figure 15AD-3.

The target is the object or area of interest – the name or position of a star, galaxy or nebula, or perhaps the coordinate position of some newly discovered object. Specify the position as a target name, for example, 3C273, M31 or 'Crab Nebula', or by using celestial coordinates.

SkyView cannot be used to look at images of objects in our solar system such as planets, asteroids or comets. SkyView is for deep space only.

SkyView's Non-Astronomers Page

Show the cadets Figure 15AD-4.

With SkyView, one can look at the sky in many different wavelengths of light. This includes the optical light that people see, along with the invisible radio, infrared, X-ray and gamma-ray data. Different kinds of objects show up in these different regimes; that is, the sky looks very different at radio wavelengths than in the optical. The Non-Astronomers page discusses each in turn, working down from the most energetic radiation, gamma-ray, through visible light and down to the radio spectrum.

The table shown in the Non-Astronomers page gives a quick overview of what can be seen in each regime and suggests a survey and image size for each. These suggested sizes are generally quite close to the defaults, which are useful for cadets who have no image size preference.

Databases accessible from SkyView are explained on the Non-Astronomers page, and include:

- EGRET >100 MeV Gamma-ray wavelengths
- PSPC 2Deg-Int X-ray wavelength
- EUVE 83 Extreme Ultraviolet (EUV) wavelength
- DSS Optical wavelength
- 2MASS K, or IRIS 100 Infrared (IR) wavelength
- FIRST or 1420 MHz Radio wavelength

While not all cadets will want to pursue these various databases, those that do will find adequate explanations on the Non-Astronomers page. Cadets should be encouraged to take advantage of NASA's explanations of the databases and how to use them.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. What is NASA's SkyView?

Q2. Where can more information about operating SkyView be found?

Q3. What two parameters are required to operate SkyView?

ANTICIPATED ANSWERS

A1. SkyView is a virtual observatory on the Internet, which generates images of any part of the sky.

A2. On SkyView's Non-Astronomers page.

A3. The coordinates of the sky to be viewed and the database to be accessed.

Teaching Point 2	Discuss SKY-MAP.ORG
Time: 5 min	Method: Interactive Lecture

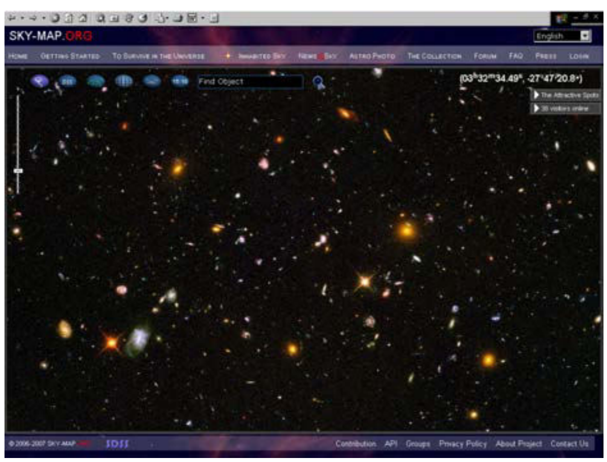
SKY-MAP.ORG

SKY-MAP.ORG is an interactive information-management system, which encompasses the entire universe. The basic element of the system is a detailed map of the sky that depicts more than half a billion celestial objects. Instructions are provided on the display. No additional instructions are necessary to browse the map or change its scale.

By using the smallest scale, the whole sky can be viewed at once. Using the largest scale, tiny areas with distant and extremely dim celestial objects, such as distant galaxies, can be viewed – courtesy of the Hubble Space Telescope (HST).

Purpose

SKY-MAP.ORG, according to its Ontario-based creators, is an attempt to show the beauty of the universe to everybody – to small children and their parents, the amateur astronomer and the professional astrophysicist.



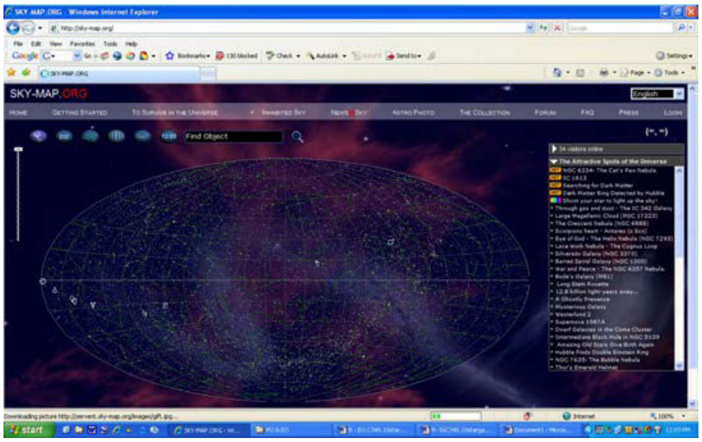
SKY-MAP.ORG, 2008, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15-11-1 The View From the Hubble Space Telescope

Show the cadets Figure 15AE-1.

How to Access SKY-MAP.ORG

1. Type http://sky-map.org in the address field on the Internet.
2. On the first screen presented, click on the "Home" button above the top of the star-field and the full universe, seen from Earth, will be shown.



SKY-MAP.ORG, 2008, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15-11-2 SKY-MAP.ORG Home Page

Show the cadets Figure 15AE-2.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. What is SKY-MAP.ORG?

Q2. Where are operating instructions for SKY-MAP.ORG found?

Q3. Where is SKY-MAP.ORG based?

ANTICIPATED ANSWERS

A1. SKY-MAP.ORG is an interactive information-management system which encompasses the entire outer space.

A2. Instructions are provided on the display.

A3. Ontario.

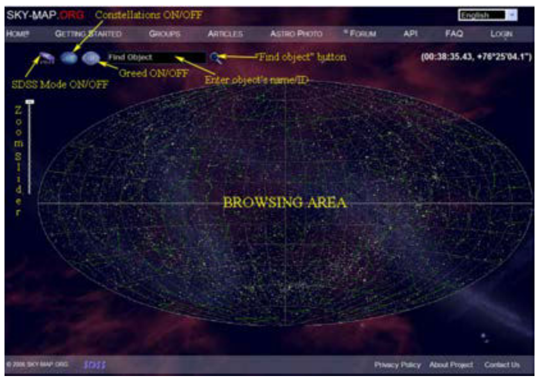
Teaching Point 3 | **Explain the SKY-MAP.ORG User Interface**

Time: 15 min | Method: Interactive Lecture

THE SKY-MAP.ORG USER INTERFACE

When using SKY-MAP.ORG, the browsing area of the screen portrays the selected view of the sky.

Show the cadets Figure 15AE-3.



SKY-MAP.ORG, 2008, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15-11-3 SKY-MAP.ORG Instruction Page

PROGRAM CONTROL FEATURES

Placing the mouse cursor over a button without clicking reveals the purpose of the control button at the top of the browsing area. As the program becomes more sophisticated, new buttons will be added. The basic controls needed to navigate are shown in Figure 15-11-3. The "Home" button returns the program to the home page showing the entire night sky as seen from the Solar system.

SKY-MAP.ORG offers two different browsing modes:

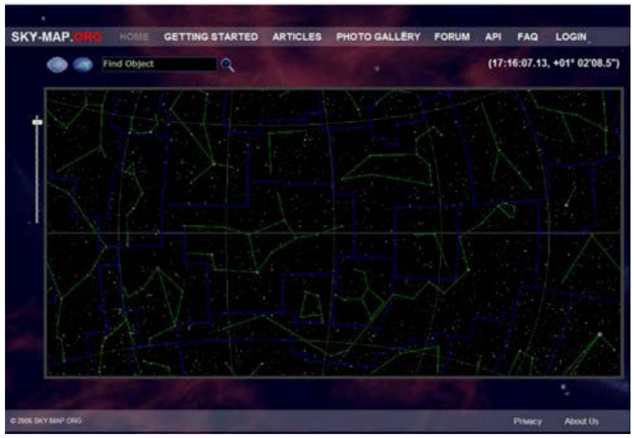
- Normal Mode, and
- Sloan Digital Sky Survey (SDSS) Mode.

Normal Mode

Show the cadets Figure 15AE-4.

The image in this figure shows the sky in Normal Mode. When in Normal Mode, SKY-MAP.ORG can access various databases to display the desired fields of view.

In the example shown, a planar projection of the whole sky is seen. Pointing the mouse at any object inside the browsing area will cause an information window to automatically appear, providing basic scientific data about the object. Left-clicking on the zoom slider causes the scale of the sky map to be changed, thereby altering the detail of the browsing area.



SKY-MAP.ORG, 2008, “SKY-MAP.ORG”. Retrieved March 19, 2008, from http://sky-map.org/

Figure 15-11-4 SKY-MAP.ORG Normal Mode

In this figure, the scale has been changed to a higher magnification so that only a portion of the sky can be viewed. The scale can be enlarged again using the zoom slider, to view very faint objects.

An Object’s Basic Information Window (BIW)

If the mouse cursor is close enough to an object (or on an object), its BIW appears, showing the data about the object. The basic data includes ID, names, constellations, exact coordinates, distances from Earth and apparent magnitudes. Left-clicking once while the BIW is still open, causes the object page to open. An object page contains detailed information about its star. In addition an object page displays all photo images where the star is present, articles and all external links about the star.

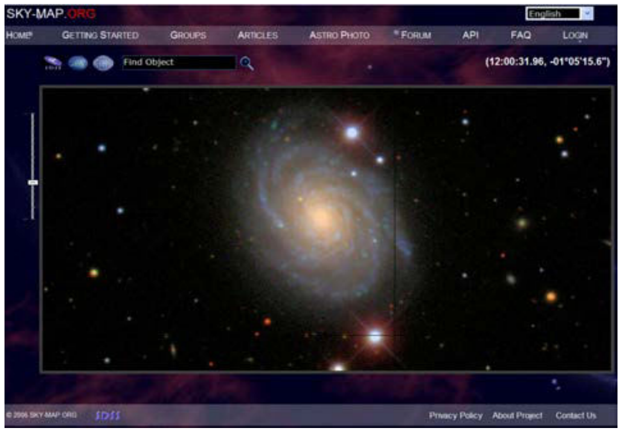
To view the stars at this moment, use the button provided with the correct time shown. When the button is pushed, the program asks for the user’s location. When the user enters the name of the closest town or the latitude and longitude, the star field that is overhead will be presented. This feature only works in Normal Mode, not in SDSS Mode.

SDSS MODE

Show the cadets Figure 15AE-5.

This figure shows a view of the browsing area in SDSS mode. In this case, SKY-MAP.ORG has found galaxy NGC 4030 in constellation Virgo. NGC 4030 is at celestial coordinates:

- Right ascension: 12 hours 00 minutes 23.40 seconds
- Declination: -01°06'03.0"



SKY-MAP.ORG, 2008, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15-11-5 Spiral Galaxy in SDSS Mode

When online, the photographic plate can be found by entering the name NGC 4030 into the "Find Object" text box or by entering the coordinates as right ascension followed by a comma and then declination. If coordinates are entered, however, considerable magnification must be applied to see NGC 4030. At this scale, it is only magnitude 0, appearing as a bright star.

Star brightness is called magnitude. The lower the magnitude, the brighter the object. The brightest star visible in the night sky is Sirius, classified as a magnitude of −1.

Sirius, the brightest star, is found at coordinates 06 45 08.90, -16 42 58.0 in Normal Mode. SDSS does not currently cover this part of the sky, but many astro photos of Sirius can be located through Sirius' BIW.

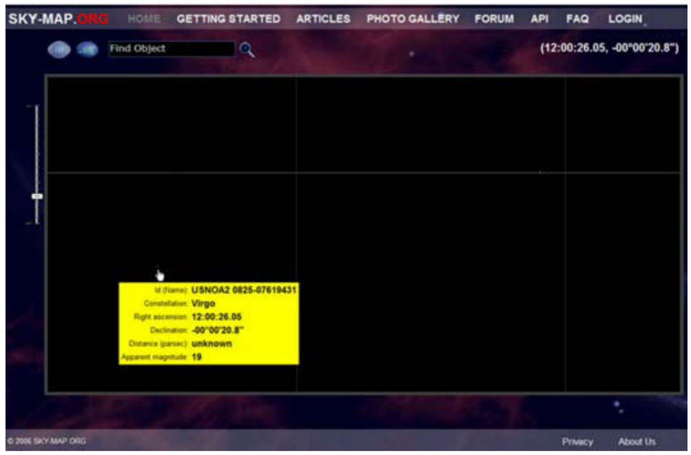
Navigating in Normal Mode

Normal Mode uses a drag-and-drop operation to shift the sky in the browsing area. To move the browsing area, place the mouse in the browsing area without pointing at any object. Press and hold the left button of the mouse and move the mouse – the star field will move with the mouse cursor.

There are about 500 million stars in the databases. Only a small amount of these stars can be displayed simultaneously in the browsing area at any given period of time. Faint celestial objects (the less bright stars) can be viewed by increasing the scale of the map.

Show the cadets Figure 15AE-6.

This figure is a view, at a large scale, corresponding to high magnification, at the right ascension and declination coordinates shown near the top right corner of the screen.



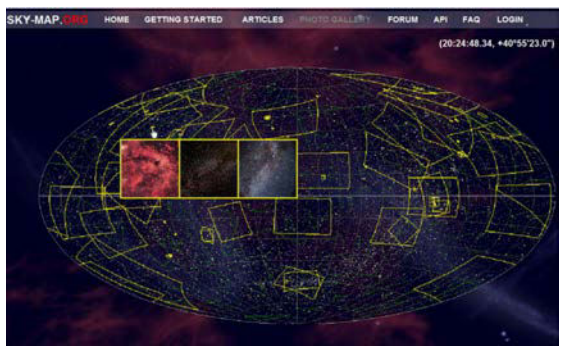
SKY-MAP.ORG, 2006, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15-11-6 Magnitude 19 in Virgo

In the example there are only two stars present in the browsing area. Both objects have a magnitude close to 19. That means these two stars can only be seen with powerful telescopes.

Photo Gallery

From the main menu, the photo gallery page with photo images can be accessed. The photo gallery index is a view similar to Figure 15AE-7.



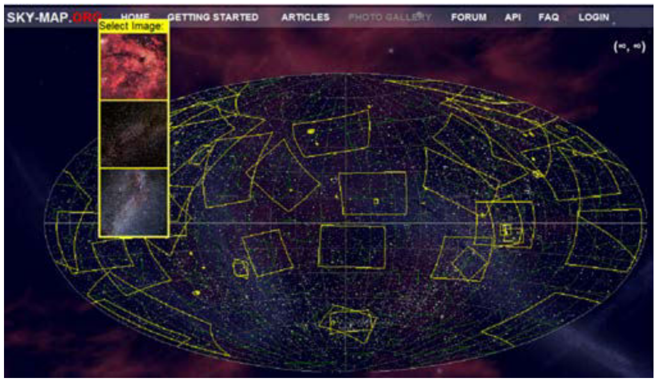
SKY-MAP.ORG, 2006, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15-11-7 SKY-MAP.ORG Photo Gallery

Show the cadets Figure 15AE-7.

Each field with yellow borders determines the boundaries of a star field photograph. When the mouse cursor is inside these boundaries, a minimized version of the photograph appears near the pointer. If the mouse cursor points to the area where fields meet, the photographs of all the fields will be displayed. For example, in this figure, the mouse points to the intersection of three different fields. The user can see the minimized versions of all three images. Left-clicking the mouse will change the mode to "Select Image" as shown in the next figure.

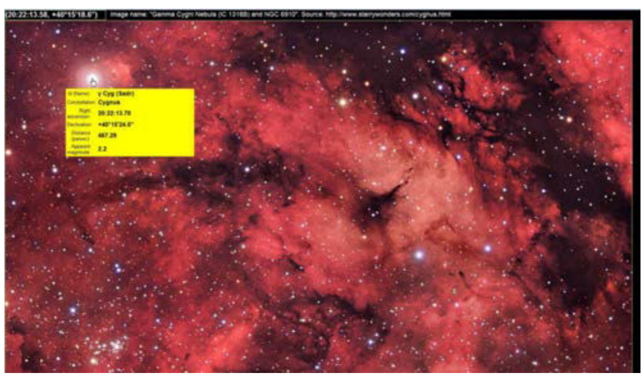
Show the cadets Figure 15AE-8.



SKY-MAP.ORG, 2006, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15-11-8 Image Selection

Clicking on the desired image in Figure 8 will load it as shown in Figure 15-11-9.



SKY-MAP.ORG, 2006, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15-11-9 Gamma Cygni Nebula Image Selected

Show the cadets Figure 15AE-9.

Pointing the mouse on an object on the photograph causes the object's BIW to open exactly the same way as it did in the browsing area. Left-clicking on the object loads the object's page. The current coordinates of the mouse will be shown, with the original source directly above it.

CATALOGUES AND DATABASES AVAILABLE FOR ACCESS

Infrared Astronomical Satellite (IRAS) Sky Survey

The IRAS conducted a survey of 98 percent of the sky from low Earth orbit during a ten-month period from January to November 1983. The purpose of the survey was to produce an extremely reliable catalogue of infrared point sources at a sensitivity that was unobtainable from within the Earth's atmosphere. The stability of the orbiting IRAS infrared detectors allowed the viewing of extended, or non-point-like, astronomical sources with the IRAS survey data.

H-ALPHA SKY SURVEY

H-alpha is a particular frequency of radiation associated with hydrogen atoms. Hydrogen is the primary component of celestial nebulae. H-alpha can indicate the shape and size of a gas cloud.

Astro Photo Survey

SKY-MAP.ORG's Astro Photo Survey is a collection of astronomical photos. Credit is usually given at the top of the individual photo so that the user knows where it originated.

Sloan Digital Sky Survey (SDSS)

Simply put, the SDSS is the most ambitious astronomical survey ever undertaken. When completed, it will provide detailed optical images covering more than a quarter of the sky, and a three-dimensional map of about a million galaxies and quasars, which are extremely bright, mysterious objects. As the survey progresses, the data is released to the scientific community and general public in annual increments.

The SDSS uses a dedicated, 2.5-metre telescope on Apache Point, New Mexico, equipped with two powerful special-purpose instruments. The 120-megapixel camera can image 1.5 square degrees of sky at a time, about eight times the area of the full moon. A pair of spectrographs fed by optical fibres measure spectra of (and hence distances to) more than 600 galaxies and quasars in a single observation. A custom-designed set of software data pipelines keeps pace with the enormous data flow from the telescope.

This data, as well as more catalogues and additional databases, will be added from time to time to the list of images that SKY-MAP.ORG can access.

Give each cadet a copy of the Astronomy Basics handout located at Annex AF.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. What are the two modes that SKY-MAP.ORG can operate in?

Q2. In the SKY-MAP.ORG Photo Gallery, what marks the boundaries of a star field photograph?

Q3. What can be entered into the "Find Object" text box to select a target object?

ANTICIPATED ANSWERS

A1. Normal Mode and SDSS Mode.

A2. Yellow borders.

A3. The object's name or the object's celestial coordinates.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. Where is SKY-MAP.ORG based?

Q2. What two parameters are required to operate NASA's SkyView?

Q3. When completed, approximately how much of the sky will be mapped in SDSS Mode?

ANTICIPATED ANSWERS

A1. Ontario.

A2. The coordinates of the sky to be viewed and the database to be accessed.

A3. When completed, it will provide detailed optical images covering more than a quarter of the sky.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Industrialization and the growth of cities has made viewing the sky difficult for the majority of Canadians but online stargazing provides an alternative way to pursue this interesting hobby.

INSTRUCTOR NOTES/REMARKS

N/A.

REFERENCES

C3-230 ET.SKY-MAP. (2008). *SKY-MAP.ORG*. Retrieved February 8, 2008, from http://sky-map.org/.

C3-231 NASA HEASARC. (2008). *SkyView*. Retrieved February 8, 2008, from http://skyview.gsfc.nasa.gov/.

ASTRONAUT MARC GARNEAU

Canadian Space Agency, 2008, Image Gallery: Marc Garneau (STS-97). Retrieved March 2, 2008, from http://www.espace.gc.ca/asc/app/gallery/results2.asp?session=&image_id=garrneau-01

Figure 15A-1 Astronaut Marc Garneau

ASTRONAUT MARC GARNEAU

Marc Garneau was a Captain (Navy) in the Canadian Forces and was Canada's first astronaut.

MISSIONS

A veteran of three space flights (STS-41G in 1984, STS-77 in 1996 and STS-97 in 2000), Marc Garneau has logged over 677 hours in space.

STS-41G

Mission: Earth Radiation Budget Satellite (ERBS).

Space Shuttle: *Challenger*.

Launched: October 5, 1984 at 7:03:00 a.m. EDT.

Landed: October 13, 1984 at 12:26:33 p.m. EDT.

Mission Duration: 8 days.

Orbit Altitude: 218 nautical miles.

This was the first flight to include two women, Sally Ride and Kathryn Sullivan. Sullivan was the first American woman to walk in space. The ERBS was deployed less than nine hours into the flight. As well, the Office of Space and Terrestrial Applications-3 (OSTA-3) carried three experiments in the payload bay. Components of Orbital Refueling System (ORS) were connected, demonstrating it is possible to refuel satellites in orbit.

Other payloads were:

- Large Format Camera (LFC),
- IMAX Camera, flying for the third time, and
- Canadian Experiments (CANEX), including:
  - Auroral Photography Experiment (APE),
  - Radiation Monitoring Equipment (RME), and
  - Thermoluminiscent Dosimeter (TLD).

STS-77

Mission: SPACEHAB; SPARTAN Inflatable Antenna Experiment (IAE).

Space Shuttle: *Endeavour*.

Launched: May 19, 1996, 6:30:00 a.m. EDT.

Landed: May 29, 1996, 7:09:18 a.m. EDT.

Mission Duration: 10 days.

Orbit Altitude: 153 nautical miles.

The fourth shuttle flight of 1996 was highlighted by four rendezvous activities with two different payloads. Primary payloads, all located in the cargo bay, were the SPACEHAB-4 pressurized research module, the IAE mounted on a Spartan 207 free-flyer and a suite of four technology demonstration experiments known as Technology Experiments for Advancing Missions in Space (TEAMS).

Using the Canadarm, the Spartan free-flyer (a platform for experiments) was deployed with the 60 kg (132 lbs) IAE antenna structure inflated to its full size of 15 m (50 feet) in diameter–about the size of a tennis court.

Potential benefits of inflatable antennas over conventional rigid structures include their lower development costs, greater reliability, and lower mass and volume requiring less stowage space and potentially a smaller launch vehicle.

TEAMS experiments were:

- Global Positioning System (GPS) Attitude and Navigation Experiment (GANE),
- Vented Tank Resupply Experiment (VTRE), and
- Liquid Metal Thermal Experiment (LMTE).

Aquatic Research Facility (ARF) experiments also took place. This was a joint Canadian Space Agency/NASA project that allowed investigation of a wide range of small aquatic species, including starfish, mussels and sea urchins.

STS-97

Mission: International Space Station Assembly Flight 4A.

Space Shuttle: *Endeavour*.

Launched: November 30, 2000, 10:06 p.m. EST.

Landed: December 11, 2000, 6:04 p.m. EST.

Mission Duration: 11 days.

Orbit Altitude: 200 nautical miles.

During their 11-day mission, the astronauts completed three spacewalks and extravehicular activities (EVAs), to:

- deliver and connect the first set of solar arrays to the International Space Station (ISS);
- prepare a docking port for arrival of the US Laboratory Destiny;
- install Floating Potential Probes to measure electrical potential surrounding the station;
- install a camera cable outside the Unity module; and
- transfer supplies, equipment and refuse between *Endeavour* and the station.

On flight day three, *Endeavour* was linked to the ISS while orbiting 200 nautical miles above northeast Kazakhstan. Extravehicular mobility units (EMUs), the Simplified Aid for EVA Rescue (SAFER) units, the Canadarm Remote Manipulator System (RMS), the Orbiter Space Vision System (OSVS) and the Orbiter Docking System (ODS) were all checked. Also, an ODS camera was installed.

From inside *Endeavour*, Mission Specialist Marc Garneau used the Canadarm RMS to remove the P6 truss from the payload bay, manoeuvring it into an overnight park position to warm its components. Shuttle astronauts moved through Endeavour’s docking tunnel and opened the hatch to the ISS docking port to leave supplies and computer hardware on the doorstep of the station. On flight day four, the crew entered the Unity module for the first time.

On flight day eight, the STS-97 crew paid the first visit to the Expedition One crew residing in the space station. Until then the shuttle and the station had kept one hatch closed to maintain respective atmospheric pressures, allowing the shuttle crew to conduct their spacewalks and mission goals. After a welcome ceremony and briefing, the eight spacefarers conducted structural tests of the station and its solar arrays, transferred equipment, supplies and refuse back and forth between the spacecraft.

On flight day nine, the two crews completed final transfers of supplies to the station and other items to be returned to earth. The *Endeavour* crew bade farewell to the Expedition One crew at 10:51 a.m. EST and closed the hatches between the spacecraft. After being docked together for 6 days, 23 hours and 13 minutes, *Endeavour* undocked from the station and made an hour-long, tail-first circle of the station. The undocking took place 204 nautical miles above the border of Kazakhstan and China. The final separation burn took place near the northeast coast of South America.

PLACE AND DATE OF BIRTH

Born February 23, 1949 in Quebec City.

EDUCATION

Marc Garneau's education includes:

- Early education in Quebec City, Saint-Jean-sur-Richelieu in Quebec and in London, England;
- Bachelor of Science degree in Engineering Physics from the Royal Military College of Kingston in 1970;
- Doctorate in Electrical Engineering from the Imperial College of Science and Technology, London, England, in 1973; and
- Attended the Canadian Forces Command and Staff College of Toronto in 1982–1983.

PROFESSIONAL EXPERIENCE

Marc Garneau was a Combat Systems Engineer in HMCS Algonquin from 1974 to 1976. While serving as an instructor in naval weapon systems at the Canadian Forces Fleet School in Halifax in 1976–77, he designed a simulator for use in training weapons officers in the use of missile systems aboard Tribal class destroyers. He served as Project Engineer in naval weapon systems in Ottawa from 1977 to 1980. Garneau returned to Halifax with the Naval Engineering Unit, which troubleshoots and performs trials on ship-fitted equipment, and he helped develop an aircraft-towed target system for the scoring of naval gunnery accuracy. Promoted to Commander in 1982 while at Staff College, Garneau was transferred to Ottawa in 1983 to become design authority for naval communications and electronic warfare equipment and systems. In January 1986, he was promoted to Captain. Garneau retired from the Navy in 1989.

In February 2001, Marc Garneau was appointed Executive Vice President of the Canadian Space Agency. He was subsequently appointed President of the Canadian Space Agency, effective November 22, 2001. He resigned from this position on November 28, 2005, to run for office in a federal election.

SPECIAL HONOURS

Marc Garneau's special honours include:

- Athlone Fellowship,
- National Research Council (NRC) Bursary,
- National Honourary Patron of Hope Air and Project North Star,
- President of the Board of the McGill Chamber Orchestra,
- Officer of the Order of Canada,
- promoted Companion of the Order of Canada,
- named Chancellor of Carleton University,
- recipient of the Prix Montfort en sciences,
- recipient of the Queen Elizabeth II Golden Jubilee Medal,

- recipient of the NASA Exceptional Service Medal,
- recipient of the NASA Space Flight Medals (1984, 1996, 2000),
- recipient of the Canadian Forces Decoration (military),
- co-recipient of the F. W. (Casey) Baldwin Award,
- awarded honourary advanced degrees from:
  - University of Ottawa,
  - Collège militaire royal de Saint-Jean,
  - Université Laval,
  - Technical University of Nova Scotia,
  - Royal Military College,
  - York University, and
  - University of Lethbridge.

AFFILIATIONS

Marc Garneau’s affiliations include:

- honorary Fellow of the Canadian Aeronautics and Space Institute,
- member of the Association of Professional Engineers of Nova Scotia,
- member of the Navy League of Canada,
- honorary Member of the Canadian Society of Aviation Medicine, and
- member of the International Academy of Astronautics.

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ASTRONAUT ROBERTA BONDAR

Canadian Space Agency, 2008, Image Gallery: Roberta Lynn Bondar. Retrieved March 2, 2008, from http://www.space.gc.ca/asc/app/gallery/gallery/hight/cd_01_11.JPG

Figure 15B-1 Astronaut Roberta Bondar

ASTRONAUT ROBERTA BONDAR

Roberta Bondar enjoys flying, hot air ballooning, canoeing, biking, target shooting (rifle, handgun), fishing, cross-country skiing and hiking.

MISSIONS

In early 1990, Roberta Bondar was designated a prime Payload Specialist for the first International Microgravity Laboratory Mission (IML-1).

STS-42

Mission: IML-1.

Space Shuttle: *Discovery*.

Launched: January 22, 1992, 9:52:33 a.m. EST.

Landed: January 30, 1992, 8:07:17 a.m. PST.

Mission Duration: 8 days.

Orbit Altitude: 163 nautical miles.

The primary payload for STS-42 was the IML-1, making its first flight and using the pressurized Spacelab module. The international crew was divided into two teams for around-the-clock research on the human nervous system's adaptation to low gravity and the effects of microgravity on other life forms such as shrimp eggs, lentil seedlings, fruit fly eggs and bacteria. Materials processing experiments were also conducted, including crystal growth from a variety of substances such as enzymes, mercury iodide and a virus.

Other experiments during STS-42 were:

- Gelation of Sols: Applied Microgravity Research-1 (GOSAMR-1),
- IMAX camera,
- Investigations into Polymer Membrane Processing (IPMP),
- Radiation Monitoring Experiment III (RME III), and
- Shuttle Student Involvement Program (SSIP) experiments.

PLACE AND DATE OF BIRTH

Born December 4, 1945 in Sault Ste. Marie, Ont.

EDUCATION

Roberta Bondar's education includes:

- Elementary and secondary school in Sault Ste. Marie, Ont.,
- BSc in zoology and agriculture from the University of Guelph,
- MSc in experimental pathology from the University of Western Ontario,
- Doctorate in neurobiology from the University of Toronto,
- Doctor of Medicine from McMaster University, and
- Certification in scuba diving and parachuting.

PROFESSIONAL EXPERIENCE

Roberta Bondar was a neurologist and a clinical and basic science researcher in the nervous system. As an undergraduate student she worked for six years for the federal Fisheries and Forestry Department on genetics of the spruce budworm with reference to the visual system. After internship in internal medicine at Toronto General Hospital, she completed post-graduate medical training in neurology at the University of Western Ontario and in neuro-ophthalmology at Tuft's New England Medical Center (Boston) and at the Playfair Neuroscience Unit of Toronto Western Hospital. Bondar was appointed assistant professor of medicine (neurology) in 1982–84 at McMaster University. She specialized in carotid and transcranial ultrasound at the Pacific Vascular Institute, in Seattle, in 1988.

Bondar was one of the six Canadian astronauts selected in December, 1983 and she began astronaut training in February, 1984. In 1985 she was named chairperson of the Canadian Life Sciences Subcommittee for Space Station. She served as a member of the Ontario Premier's Council on Science and Technology. She was a Civil Aviation medical examiner and a member of the scientific staff of Sunnybrook Health Science Centre. As an astronaut, she has conducted research into blood flow in the brain during microgravity, lower body negative pressure and various pathological states.

Roberta Bondar left the Canadian Space Agency effective September 4, 1992, to pursue her research.

SPECIAL HONOURS

Roberta Bondar's special honours include:

- recipient of Ontario Graduate Fellowship,
- recipient of National Research Council (NRC) Scholarship,
- recipient of NRC Postdoctorate Fellowship,
- recipient of Ontario Ministry of Health Fellowship,
- recipient of Medical Research Council Fellowship,
- recipient of Career Scientist Award from the Ontario Ministry of Health,
- honourary member of Zonta International,
- honourary member Canadian Federation of University Women,
- recipient of Vanier Award from the Jaycees of Canada,
- co-recipient of the F. W. (Casey) Baldwin Award,
- honourary life member of Girl Guides of Canada,
- recipient of Senior Fellowship from Ryerson Polytechnical Institute, Toronto, and
- recipient of honourary degrees from:
  - Mount Allison University,
  - Mount St. Vincent University,
  - University of Guelph,
  - Lakehead University,
  - Algoma College,
  - Laurentian University,
  - Saint Mary's University,

  - McMaster University,
  - University of Regina,
  - University of Calgary,
  - University of Ottawa, and
  - University of Toronto.

AFFILIATIONS

Roberta Bondar's affiliations include:

- Fellow of the Royal College of Physicians and Surgeons of Canada,
- American Academy of Neurology,
- Canadian Neurological Society,
- Canadian Aeronautics and Space Institute,
- Canadian Society of Aerospace Medicine,
- College of Physicians and Surgeons of Ontario,
- Canadian Stroke Society,
- Aerospace Medical Association,
- Albuquerque Aerostat Ascension Association, and
- American Society for Gravitational and Space Biology.

ASTRONAUT STEVE MACLEAN

Canadian Space Agency, 2008, Image Gallery: Steve MacLean. Retrieved March 2, 2008, from http://www.espace.gc.ca/asc/app/gallery/results1.asp?session=

Figure 15C-1 Astronaut Steve MacLean

ASTRONAUT STEVE MACLEAN

Selected as one of the first six Canadian astronauts in December 1983, Steve MacLean began astronaut training in February 1984. From 1987 to 1993 he was the Program Manager for the Advanced Space Vision System (ASVS), a computer-based camera system designed to provide guidance data that enhances the control of both Canadarm and Canadarm2. From 1988 to 1991 he also assumed the role of Astronaut Advisor to the Strategic Technologies in Automation and Robotics (STEAR) Program.

MISSIONS

STS-52

Mission: U.S. Microgravity Payload-1 (USMP-1); Laser Geodynamic Satellite II (LAGEOS II).

Space Shuttle: Columbia.

Launched: October 22, 1992, 1:09:39 p.m. EDT.

Landed: November 1, 1992, 9:05:53 a.m. EST.

Mission Duration: 9 days.

Orbit Altitude: 163 nautical miles.

The primary mission objectives were the deployment of the LAGEOS-II, a joint effort between NASA and the Italian Space Agency (ASI), and also operation of the USMP-1.

In addition to LAGEOS II and USMP-1, other mission objectives included:

- Canadian experiments, CANEX-2, located in both the orbiter's cargo bay and mid-deck, consisting of:
  - Space Vision System (SVS),
  - Materials Exposure in Low-Earth Orbit (MELEO),
  - Queen's University Experiment in Liquid-Metal Diffusion (QUELD),
  - Phase Partitioning in Liquids (PARLIQ),
  - Sun Photospectrometer Earth Atmosphere Measurement-2 (SPEAM-2),
  - Orbiter Glow-2 (OGLOW-2),
  - Space Adaptation Tests and Observations (SATO), and
  - A small, specially marked satellite, the Canadian Target Assembly, which was deployed on day nine to support SVS experiments; and
- three independent sensors provided by the European Space Agency, including:
  - Modular Star Sensor,
  - Yaw Earth Sensor, and
  - Low Altitude Conical Earth Sensor.

STS-115

Mission: Installation of the P3/P4 truss arrays on the International Space Station.

Space Shuttle: Atlantis.

Launched: September 9, 2006 at 11:15 a.m. EDT.

Landed: September 21, 2006 at 6:21 a.m. EDT.

Mission Duration: 12 days.

Orbit Altitude: 122 nautical miles.

The STS-115 crew delivered and installed the P3/P4 truss arrays on the ISS. Three spacewalks were carried out to put the new P3/P4 truss in service. Spacewalkers, including Steve MacLean, connected power cables and activated gear readying the P3/P4, and its unfurled solar arrays, for power generation.

The STS-115 and Expedition 13 crews utilized both shuttle and station robotic arms, Canadarm and Canadarm2, during installation activities.

PLACE AND DATE OF BIRTH

Born December 14, 1954, in Ottawa, Ont.

EDUCATION

Steve MacLean's education includes:

- Primary and secondary school in Ottawa,
- Bachelor of Science (Honours) in Physics in 1977 from York University, and
- Doctorate in Physics in 1983 from York University.

PROFESSIONAL EXPERIENCE

From 1974 until 1976 Steve MacLean worked in sports administration and public relations at York University, and competed with the Canadian National Gymnastics Team from 1976 to 1977. He taught part-time at York University, from 1980 until 1983, and then became a visiting scholar at Stanford University. As a laser physicist, MacLean's research included work on electro-optics, laser-induced fluorescence of particles and crystals, and multi-photon laser spectroscopy.

MacLean was the Chief Science Advisor for the International Space Station from 1993 until 1994, when he was appointed Director General of the Canadian Astronaut Program for a two-year period.

In August 1996, MacLean began mission specialist training at the Johnson Space Center in Houston, Texas. After successfully completing basic training in 1998, he continued with advanced training while fulfilling technical duties in the NASA Astronaut Office Robotics Branch. Later, MacLean served as CapCom (Capsule Communicator) for both the ISS Program and the Shuttle Program at the Johnson Space Center.

In 2007, MacLean was Chief Astronaut for the CSA, coordinating the astronaut activities from CSA headquarters.

SPECIAL HONOURS

Steve MacLean's special honours include:

- recipient of the President's Award (Murray G. Ross Award) at York University,
- recipient of a Natural Sciences and Engineering Research Council of Canada (NSERC) Postgraduate Scholarship,
- recipient of two Ontario Graduate Scholarships,
- recipient of a NSERC Postdoctoral Fellowship, and
- recipient of honorary advanced degrees from:
    - Collège militaire royal de Saint-Jean in Que.,

- York University in Toronto, and
- Acadia University in Wolfville.

ASTRONAUT CHRIS HADFIELD

Canadian Space Agency, 2008, Image Gallery: Chris Hadfield. Retrieved March 2, 2008, from http://www.espace.gc.ca/asc/app/gallery/results1.asp?session=&search=0&ListAbsolutePage=8&root_categories=0&categories_0=0&keywords=Chris|Hadfield&images=ON

Figure 15D-1 Astronaut Chris Hadfield

ASTRONAUT CHRIS HADFIELD

In June 1992, Chris Hadfield was selected to become one of four new Canadian astronauts from a field of 5 330 applicants. He was assigned by the CSA to the NASA Johnson Space Center in Houston, Texas, in August of the same year where he addressed technical and safety issues for Shuttle Operations Development, contributed to the development of the glass shuttle cockpit, and supported shuttle launches at the Kennedy Space Center in Florida. In addition, Hadfield was NASA's Chief CapCom, the voice of mission control to astronauts in orbit, for 25 space shuttle missions. From 1996 to 2000, he represented CSA astronauts and coordinated their activities as the Chief Astronaut for the CSA.

From 2001 to 2003, Hadfield was the Director of Operations for NASA at the Yuri Gagarin Cosmonaut Training Centre (GCTC) in Star City, Russia. His work included coordination and direction of all ISS crew activities in Russia and oversight of training and crew support staff, as well as policy negotiation with the Russian Space Program and other international partners. He also trained and became fully qualified as a flight engineer cosmonaut in the Soyuz TMA spacecraft to perform spacewalks in the Russian Orlan spacesuit.

Hadfield is a civilian CSA astronaut, having retired as a Colonel from the Canadian Forces in 2003 after 25 years of military service. He was Chief of Robotics for the NASA Astronaut Office at the Johnson Space Center in Houston, Texas from 2003 to 2006, and then Chief of International Space Station Operations.

MISSIONS

STS-74

Mission: Second Shuttle-Mir Docking.

Space Shuttle: Atlantis.

Launched: November 12, 1995 at 7:30:43 a.m. EST.

Landed: November 20, 1995 at 12:01:27 p.m. EST.

Mission Duration: 8 days.

Orbit Altitude: 213 nautical miles.

This mission illustrated the international flavour of the space station effort in both the hardware and the crew. Hardware in the payload bay included:

- Canadian built Remote Manipulator System (RMS) arm,
- U.S. built Orbiter Docking System (ODS),
- Russian-Built Docking Module (DM) and solar array, and
- US/Russian built solar array.

Chris Hadfield was the fourth Canadian to fly on a shuttle but the first Canadian mission specialist. Awaiting Atlantis aboard Mir, were two Russian cosmonauts and a German cosmonaut, along with Russian and European Space Agency research samples and equipment.

On flight day three, Hadfield operated the Canadarm RMS to lift the DM from its stowed position and moved it to within five inches above the ODS in the forward part of the bay. ODS was flown on all Shuttle-Mir docking flights and served as a passageway between two spacecraft. Steering jets were then fired to push Atlantis against the DM. Once mating was confirmed, the Canadarm ungrappled from the DM and hatches between the DM and the ODS were opened.

The manual phase of rendezvous began when Atlantis was about 800 m from Mir. At 51.8 m from Mir, the approach was halted while Mir was manoeuvred into alignment for docking. After permission from flight directors in Moscow and Houston, Atlantis was moved to 9.1 m from Mir and then halted momentarily again to make final adjustments. The key camera for final approach was an elbow camera on the shuttle's Canadarm RMS.

Hatches between Mir and Atlantis were opened at 4:02 a.m. EST, November 15. Control of the DM was transferred to the Mir 20 crew. During mated operations, nearly 453.6 kg of water was transferred to Mir. Numerous experiment samples, including blood, urine and saliva, were moved to the orbiter for return to earth. The shuttle crew also brought gifts, including Canadian maple sugar candies and a guitar (second guitar on Mir). Lithium hydroxide canisters – a late addition – were transferred to Mir in case the faulty environmental control system failed again and the station's air needed to be "scrubbed" clean. The two spacecraft separated on November 18 and Atlantis began the journey home.

STS-100

Mission: International Space Station Assembly Flight 6A.

Space Shuttle: *Endeavour*.

Launched: April 19, 2001, 2:40:42 p.m. EDT.

Landed: May 1, 2001, 9:10:42 p.m. PDT.

Mission Duration: 12 days.

Docking with the ISS occurred at 9:59 a.m. EDT April 21. The advanced robotic arm, called Canadarm2, was attached to a pallet on the outside of the U.S. Destiny Lab. It was later directed to walk off the pallet and grab onto an electrical grapple fixture on Destiny that would provide data, power and telemetry to the arm. Days later the arm was used to hand off the cradle, on which it rested inside Endeavour's payload bay during launch, to the orbiter's arm. The exchange of the cradle from the station's Mobile Servicing System (MMS) Canadarm2 to the shuttle's RMS Canadarm marked the first ever robotic-to-robotic transfer in space.

As the astronauts rewired power and data connections for the arm, the backup power circuit failed to respond to commands from station flight engineer Susan Helms, who was operating from a workstation inside Destiny. Disconnecting and reconnecting the cables at the base of the arm resolved the situation and the redundant power path to the arm was then completed.

Other crew activities during the mission included attaching a UHF antenna on the outside of the station and inside, calibrating the Space Vision System – an alignment aid for operating the robotic arm – plus helping repair the space station's treadmill and also filming for IMAX.

ISS Trouble in Space

Computer problems surfaced late on April 24 when flight controllers for the station experienced a loss of command and control computer No. 1, one of three computers on board for systems management. The result was a loss of communication and data transfer between the space station Flight Control Room in Houston and the station.

Communication was routed through *Endeavour*, which enabled the station crew and flight controllers to talk to one another. No computer problems were encountered on *Endeavour*. Activities involving the Canadarm2 RMS were postponed.

Station flight engineer Susan Helms, using a laptop computer, was able to restore the ground's ability to monitor and send commands to the station's US systems. Through the laptop, data from the station computers could be transmitted to the ground for analysis and investigation of the problems.

Computer restoration continued successfully, especially C&C number three. C&C number one was found to have a failed hard drive. It was replaced by a backup payload computer.

Ground controllers successfully synchronized timers on all on-board computers and investigated an error in the software load that might have caused the computer problem. With one operational C&C computer in Destiny and a back-up laptop in Unity, the undocking procedure for Raffaello was given the go-ahead.

Endeavour undocked from the space station April 29, fired a separation burn and headed for home.

PLACE AND DATE OF BIRTH

Born August 29, 1959, in Sarnia and raised in Milton, Ont.

EDUCATION

Chris Hadfield's education includes:

- Graduate as an Ontario Scholar from Milton District High School,
- Bachelor degree in mechanical engineering (with honours) from RMC,
- Post-graduate research at the University of Waterloo, and
- Master of Science (aviation systems) from the University of Tennessee.

PROFESSIONAL EXPERIENCE

In total, Chris Hadfield has flown over 70 different types of aircraft. Raised on a corn farm in southern Ontario, he became interested in flying at a young age. As an air cadet, he won a glider pilot scholarship at age 15 and a power scholarship at age 16. He also taught skiing and ski racing part- and full-time for 10 years.

Hadfield underwent basic flight training in Portage La Prairie, Man., for which he was named top pilot in 1980. In 1983, he took honours as the overall top graduate from Basic Jet Training in Moose Jaw, Sask. and, in 1984–1985, he trained as a fighter pilot in Cold Lake, Alta. on CF-5s and CF-18s. For the next three years Hadfield flew CF-18s for the North American Aerospace Defence Command (NORAD) with 425 Squadron, during which time he flew the first CF-18 intercept of a Soviet "Bear" aircraft. He attended the United States Air Force (USAF) Test Pilot School at Edwards Air Force Base, in California and, upon graduation, served as an exchange officer with the US Navy at Strike Test Directorate at the Patuxent River Naval Air Station.

Colonel Hadfield's military accomplishments from 1989 to 1992 included:

- testing the F/A-18 and A-7 aircraft;
- completing the first military flight of F/A-18 enhanced performance engines;
- developing a new handling qualities rating scale for high angle-of-attack test;
- participating in the F/A-18 out-of-control recovery test program;
- performing research with NASA on pitch control margin simulation and flight; and
- piloting the first flight test of the National Aerospace Plane external-burning hydrogen propulsion engine.

SPECIAL HONOURS

Chris Hadfield's special honours include:

- recipient of Liethen-Tittle Award 1988 (top pilot graduate of the USAF Test Pilot School),
- recipient of U.S. Navy Test Pilot of the Year (1991),
- recipient of honorary Doctorate of Engineering from the Royal Military College (1996),
- recipient of Member of the Order of Ontario (1996),
- recipient of honorary Doctorate of Laws from Trent University (1999),

- recipient of Vanier Award (2001),
- recipient of Meritorious Service Cross (2001),
- recipient of NASA Exceptional Service Medal (2002),
- recipient of Queen Elizabeth II Golden Jubilee Medal (2003),
- inducted into Canada's Aviation Hall of Fame (2005), and
- commemorated on Royal Canadian Mint silver and gold coins for his spacewalk to install Canadarm2 on the ISS (2006).

AFFILIATIONS

Chris Hadfield's affiliations include:

- Royal Military College Club,
- Society of Experimental Test Pilots,
- Canadian Aeronautics and Space Institute,
- Honourary Patron of Lambton College,
- Trustee of Lakefield College School,
- Board member of the International Space School Foundation, and
- Executive with the Association of Space Explorers.

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ASTRONAUT BOB THIRSK

Canadian Space Agency, 2008, Image Gallery: Bob Thirsk. Retrieved March 2,2008, from http://www.space.gc.ca/asc/app/gallery/results2.asp?session=&image_id=Thrisk-1001

Figure 15E-1 Astronaut Robert (Bob) Thirsk

ASTRONAUT BOB THIRSK

In June and July 1996, Thirsk flew as a payload specialist aboard space shuttle mission STS-78, the Life and Microgravity Spacelab (LMS) mission. During this 17-day flight aboard Columbia, he and his six crewmates performed 43 international experiments devoted to life science and materials science.

In 2008, Thirsk was assigned to a long-duration flight as a member of Expedition 19 on the ISS, with duties that include robotic operations and conducting scientific experiments on behalf of Canadian and international researchers.

MISSIONS:

STS-78

Mission: LMS.

Space Shuttle: Columbia.

Launched: June 20, 1996, 10:49:00 a.m. EDT.

Landed: July 7, 1996, 8:36:45 a.m. EDT.

Mission Duration: 17 days.

Orbit Altitude: 150 nautical miles.

Mission Highlights

Five space agencies (NASA, European Space Agency, French Space Agency, Canadian Space Agency, and Italian Space Agency) and research scientists from 10 countries worked together on primary payload experiments of LMS. More than 40 experiments flown were grouped into two areas:

- life sciences, which included human physiology and space biology; and
- microgravity science, which included basic fluid physics investigations, advanced semiconductor and metal alloy materials processing and medical research in protein crystal growth.

Regarding STS-78, NASA observed:

Canadian Space Agency astronaut Bob Thirsk was uniquely qualified for this mission. A bio-medical engineer and a medical doctor, his knowledge and expertise reached into many areas, notably in the physiological adaptations that occur in weightlessness as well as in microgravity experimentation relating to materials processing and fluid physics.

Since 1983, when he was selected to become an astronaut, Bob Thirsk has accumulated 16 years of operational experience. He first trained as back-up Payload Specialist to Marc Garneau for Mission 41-G in October 1984. He was an investigator for three experiments that flew on previous Spacelab missions and was an alternate Payload Specialist on the IML-1 Mission.

One of the most common physiological changes astronauts must live with in a weightless environment is the redistribution of body fluids which can cause discomfort or problems in space or upon returning to earth. Thirsk was leader of an international team investigating this shift of body fluids in weightlessness and its effects on the body’s venous system. He has designed an experimental antigravity suit, a pressure suit he believes will help astronauts readapt to life back on earth.

During STS-78, Bob Thirsk participated in a number of experiments in life and microgravity sciences. Like the other six astronauts, he was both subject and researcher for several life sciences investigations. He had a major role in Canada’s Torso Rotation Experiment (TRE), designed by McGill University and sponsored by the Canadian Space Agency. TRE related eye/head/body movements to the symptoms of motion sickness that many astronauts experience. Thirsk was also involved in four muscle physiology experiments. Studies on previous missions have revealed a loss of muscle mass, biochemical changes in the muscle that oppose gravity and changes in the performance of certain muscle groups that bear weight and support the skeleton.

Dr. Thirsk had a strong interest in the lung function experiment whose goal was to explain the large differences in the ventilation and the perfusion (blood flow) to the top and bottom of the lung.

Bob Thirsk also participated in one microgravity science experiment, the Protein Crystallization Facility Experiment. The astronauts crystallized large proteins (such as DNA, RNA or viruses) that were analysed back on earth. The goal was to better understand the interactions within and between proteins and, eventually, to design better drugs to inhibit or improve certain effects.

The Columbia orbiter itself played a key part in tests to support raising the Hubble Space Telescope (HST) to a higher orbit during HST's second servicing mission. Columbia's vernier Reaction Control System jets were gently pulsed to boost the orbiter's altitude without jarring payloads. Raising the orbiter Columbia very gently, provided experience used to inform orbiter *Discovery's* later mission STS-82 how to raise HST's orbit without impacting its solar arrays. During STS-82 in February 1997, orbiter *Discovery* did indeed fire its manoeuvring jets several times to successfully boost HST to an orbit eight nautical miles higher.

PLACE AND DATE OF BIRTH

Born August 17, 1953, in New Westminster, B.C.

EDUCATION

Robert Thirsk's education includes:

- Primary and secondary schools in B.C., Alta., and Man.,
- BSc degree in Mechanical Engineering from the University of Calgary,
- MSc in Mechanical Engineering from the Massachusetts Institute of Technology (MIT),
- Doctorate of Medicine from McGill University, and
- Master of Business Administration from the MIT Sloan School of Management.

PROFESSIONAL EXPERIENCE

Robert Thirsk was in the family medicine residency program at the Queen Elizabeth Hospital in Montréal when he was selected in December 1983 for the Canadian Astronaut Program. He began astronaut training in February 1984 and served as backup payload specialist to Marc Garneau for the October 1984 space shuttle mission STS-41G.

Thirsk has been involved in various CSA projects including parabolic flight campaigns and mission planning. He served as crew commander for two space mission simulations: the seven-day CAPSULS mission in 1994, at Defence Research and Development Canada in Toronto, and the 11-day NEEMO 7 undersea mission in 2004 at the National Undersea Research Center in Key Largo, Florida. He also led an international research team investigating the effect of weightlessness on the heart and blood vessels.

In 1998, Thirsk was assigned by the CSA to NASA's Johnson Space Center in Houston to pursue mission specialist training. This training program involves advanced instruction on both shuttle and space station systems, extravehicular activity (EVA), robotic operations, and the Russian language. Within the NASA Astronaut Office, Thirsk serves as a capsule communicator (CapCom) for the International ISS program. CapComs participate in actual and simulated space missions as a communication link between the ground team at Mission Control and the astronauts in orbit. CapComs speak directly with the space station crew and assist with technical planning for the mission and last minute troubleshooting.

In 2004, Thirsk trained at the Yuri Gagarin Cosmonaut Training Centre near Moscow and became certified as a Flight Engineer for the Soyuz spacecraft. He served as backup Flight Engineer to European Space Agency (ESA) astronaut Roberto Vittori for the Soyuz 10S taxi mission to the ISS in April 2005. During the 10-day mission, Thirsk worked as Crew Interface Coordinator (European CapCom) at the Columbus Control Centre in Germany. Thirsk then returned to the Johnson Space Center in Houston to begin ISS Expedition crew training.

Further to Thirsk's CapCom training and experience for NASA missions, in 2007 he underwent Eurocom (European capsule communicator) training in Germany to support the European Space Agency's (ESA) Columbus Control Centre (COL-CC). The COL-CC provides command and control for the Columbus laboratory which was carried into orbit on February 7, 2008, by STS-122.

SPECIAL HONOURS

Bob Thirsk's special honours include:

- recipient of the Association of Professional Engineers, Geologists and Geophysicists of Alberta Gold Medal,
- recipient of the University of Calgary Distinguished Alumni Award,
- recipient of the Gold Medal of the Professional Engineers of Ontario, and
- honorary membership in the College of Physicians and Surgeons of British Columbia.

AFFILIATIONS

Bob Thirsk's affiliations include:

- Professional Engineers of Ontario,
- Canadian College of Family Physicians,
- Canadian Aeronautics and Space Institute,
- Aerospace Medical Association,
- Colleges of Physicians and Surgeons of Ontario and of British Columbia, and
- Canadian Foundation for the International Space University.

ASTRONAUT BJARNI TRYGGVASON

Canadian Space Agency, 2008, Image Gallery: Bjarni Tryggvason. Retrieved March 2, 2008, from http://www.space.gc.ca/asc/app/gallery/results2.asp?session=&image_id=astronaut

Figure 15F-1 Astronaut Bjarni Tryggvason

ASTRONAUT BJARNI TRYGGVASON

Bjarni Tryggvason is an airline transport rated pilot with more than 4 500 hours of flight experience and 1 800 hours as a flight instructor. He is active in aerobatic flight including time on the Tutor jet trainer with the Canadian Forces. He enjoys jogging, skiing and general fitness. He has two children.

MISSIONS

STS-85

Mission: Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere-Shuttle Pallet Satellite-2 (CRISTA-SPAS-02).

Space Shuttle: *Discovery*.

Launched: August 7, 1997, 10:41:00 a.m. EDT.

Landed: August 19, 1997, 7:07:59 a.m. EDT.

Mission Duration: 12 days.

Orbit Altitude: 150 nautical miles.

STS-85 carried a complement of payloads in the cargo bay that focused on Mission to Planet Earth objectives as well as preparations for ISS assembly:

- the Japanese Manipulator Flight Development (MFD),
- the Technology Applications and Science-01 (TAS-1),
- the International Extreme Ultraviolet Hitchhiker-02 (IEH-02), and
- CRISTA-SPAS-02.

This was the second flight of CRISTA-SPAS payload. CRISTA-SPAS-02 represented the fourth mission in a cooperative venture between the German Space Agency (DARA) and NASA. The payload included three telescopes and four spectrometers, deployed on flight day one, to gather data about earth's middle atmosphere. After more than 200 hours of free flight, CRISTA-SPAS-02 was retrieved on August 16. The three CRISTA telescopes collected 38 full atmospheric profiles of the middle atmosphere. A total of 22 sounding rockets and 40 balloons were launched to provide correlating data.

A complementary instrument, the Middle Atmosphere High Resolution Spectrograph Investigation (MAHRSI), provided additional data. This new information from STS-85 combined with that from the first CRISTA-SPAS flight (STS-66 in1994) was used to yield new insight into the distribution of ozone in earth's atmosphere. Once science operations were complete, CRISTA-SPAS was used in a simulation exercise to prepare for the first ISS assembly flight, STS-88.

TAS-1 was a Hitchhiker payload carrying eight experiments designed to demonstrate faster, better and cheaper avionics and processes. All these experiments were completed successfully:

- Solar Constant Experiment (SOLCON),
- Infrared Spectral Imaging Radiometer (ISIR),
- Shuttle Laster Altimeter (SLA),
- Critical Viscosity of Xenon (CVX),
- Space Experiment Module (SEM),
- Two Phase Flow (TPF),

- Cryogenic Flight Experiment (CFE), and
- Stand Alone Acceleration Measurement Device and the Wide Band Stand Alone Acceleration Measurement Device (SAAMD/WBSAAMD).

MFD was designed to evaluate use of the Small Fine Arm that will be part of the future Japanese Experiment Module's Remote Manipulator System on ISS. Despite some glitches, MFD completed a series of exercises by the crew on orbit as well as operators on ground. Two unrelated Japanese experiments, Two-Phase Fluid Loop Experiment (TPFLEX) and Evaluation of Space Environment and Effects on Materials (ESEM), were mounted near the Small Fine Arm in the payload bay.

IEH-02 was flying a second time and consisted of four experiments–all with the common objective of investigating solar extreme ultraviolet (EUV) flux and EUV emissions of the Jupiter/Io plasma torus system:

- Solar Extreme Ultraviolet Hitchhiker-2 (SEH),
- Ultraviolet Spectrography Telescope for Astronomical Research (UVSTAR),
- Distribution and Automation Technology Advancement - Colorado Hitchhiker and Student Experiment of Solar Radiation (DATA-CHASER), and
- Shuttle Glow Experiment-5 and -6.

Payloads inside the cabin included:

- Protein Crystal Growth - Single locker Thermal Enclosure System (PCG-STES),
- Midcourse Space Experiment (MSX),
- Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLEX),
- Southwest Ultraviolet Imaging System (SWUIS), used to observe the Hale-Bopp comet,
- two Get Away Special (GAS) payloads,
- Biological Research in Canisters-10 (BRIC-10), one in a series of flights,
- Solid Surface Combustion Experiment (SSCE), and
- Bioreactor Demonstration System-3 (BDS-3), a cell-biology research payload that had flown previously. On this flight, BDS was used for growing colon cancer cells to a larger size than can be achieved on earth.

The crew also worked with the Orbiter Space Vision System (OSVS), which will be used during ISS assembly. OSVS features series of dots, strategically placed on various payload and vehicle structures, which permit precise alignment and pointing capability.

PLACE AND DATE OF BIRTH

Born September 21, 1945, in Reykjavik, Iceland.

EDUCATION

Bjarni Tryggvason's education includes:

- Primary school in N.S. and B.C.,
- High school in Richmond, B.C.,
- BASc in Engineering Physics from the University of British Columbia, and
- completed postgraduate work in engineering with specialization in applied mathematics and fluid dynamics at the University of Western Ontario.

PROFESSIONAL EXPERIENCE

Bjarni Tryggvason was a meteorologist with the cloud physics group at the Meteorlogic Service Canada (formerly the Atmospheric Environment Service) in Toronto in 1972 and 1973. After that, he served as a research associate in industrial aerodynamics at the Boundary Layer Wind Tunnel Laboratory at the University of Western Ontario from 1974 to 1979.

Tryggvason was a guest research associate at Kyoto University, in Kyoto, Japan, in 1979 and at James Cook University of North Queensland, in Townsville, Australia in 1980. He was a lecturer in Applied Mathematics at the University of Western Ontario from 1980 to 1982.

From 1982 to 1984, Tryggvason was a research officer at the Low Speed Aerodynamics Laboratory at the National Research Council of Canada (NRC) and was a lecturer at the University of Ottawa and at Carleton University from 1982 to 1992.

Selected as one of the original six Canadian astronauts in December 1983, Tryggvason trained as a backup payload specialist for the CANEX-2 set of experiments, which flew on Mission STS-52 in October 1992. He was also the project engineer for the Space Vision System Target Spacecraft, which was deployed during that mission.

Tryggvason also served as the principal investigator for the following projects:

- development of the Large Motion Isolation Mount (LMIM), which flew numerous times on NASA KC-135 and DC-9 aircraft,
- Microgravity vibration Isolation Mount (MIM), which operated on the Russian space station, Mir, from April 1996 until January 1998 to support several Canadian and US experiments in material science and fluid physics, and
- the MIM-2 which flew on STS-85 in August 1997.

He was the originator and technical director during the early development phase of the Microgravity Vibration Isolation Subsystem (MVIS), which the CSA developed for the European Space Agency Fluid Science Laboratory for the ISS.

On August 7, 1997, Tryggvason flew as a payload specialist aboard Space Shuttle *Discovery* on Mission STS-85. His primary role was to test MIM-2 and perform fluid science experiments designed to examine sensitivity to spacecraft vibrations, in order to develop a better understanding of the need for systems such as the MIM on the ISS and to study the effect vibrations have on the many experiments performed on the ISS.

In August 1998, Tryggvason was invited to take part in NASA mission specialist training held at the Johnson Space Center in Houston, Texas. His class underwent two years of physical and academic training and was the first group of astronauts to be trained as both mission specialists for the space shuttle and as potential crewmembers for the ISS.

Following completion of mission specialist training, Tryggvason's NASA duties included serving as a crew representative for the Shuttle Avionics Integration Laboratory (SAIL), which is used to test shuttle flight software prior to onboard use. He also supported integrated simulations on the ISS Training Facility at the Johnson Space Center in Houston, Texas, and served as a CSA representative on the NASA Microgravity Measurement Working Group and on the ISS Microgravity Analytic Integration Team.

From mid 2001 to 2003, Tryggvason worked in the private sector while on leave from the CSA. He returned to work at the CSA in 2004. He has held the position of visiting professor at the University of Western Ontario. He has written more than 50 published papers and holds three patents.

SPECIAL HONOURS

Bjarni Tryggvason's special honours include:

- recipient of the Canadian Space Agency Innovators Award,
- recipient of the Order of the Falcon from Iceland,
- recipient of the NASA Space Flight Medal, and
- recipient of the Doctorate of Philosophy (honoris causa) degrees, from:
  - University of Iceland, and
  - University of Western Ontario.

AFFILIATIONS

Bjarni Tryggvason's affiliations include the Canadian Aeronautics and Space Institute.

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ASTRONAUT DAVE WILLIAMS

Canadian Space Agency, 2008, Image Gallery: Dave Williams. Retrieved March 2, 2008, from http://spaceflight.nasa.gov/gallery/images/shuttle/sts-118/html/jsc2001-00190.html

Figure 15G-1 Astronaut Dave Williams

ASTRONAUT DAVE WILLIAMS

Dave Williams is married and has two children. He enjoys flying, scuba diving, hiking, sailing, kayaking, canoeing, downhill and cross-country skiing.

MISSIONS

STS-90

Mission: Neurolab (the final Spacelab mission).

Space Shuttle: Columbia.

Launched: April 17, 1998, 2:19:00 p.m. EDT.

Landed: May 3, 1998, 12:08:59 p.m. EDT.

Mission Duration: 16 days.

Orbit Altitude: 150 nautical miles.

The launch of Columbia was postponed on April 16 for 24 hours due to difficulty with one of Columbia's two network signal processors, which format data and voice communications between the ground and the space shuttle. The network signal processor 2 was replaced, and Columbia lifted off on April 17.

Mission Highlights

Neurolab's 26 experiments targeted one of the most complex and least understood parts of the human body – the nervous system. The primary goals were to conduct basic research in neurosciences and expand understanding of how the nervous system develops and functions in space. Test subjects were crew members, rats, mice, crickets, snails and two kinds of fish. This was a cooperative effort of the Canadian Space Agency and several other national space agencies, including ESA (European Space Agency), NASA (USA), CNES (France), DARA (Germany) and NASDA (Japan). Most experiments were conducted in the pressurized Spacelab long module located in Columbia's X bay. This was the 16th and last scheduled flight of the ESA-developed Spacelab module although the Spacelab pallets continued to be used on the ISS.

STS-118

Launch: Aug. 8, 2007, 6:36 p.m. EDT.

Landed: Aug. 21, 2007,12:33 p.m. EDT.

Orbiter: *Endeavour*.

Mission Number: STS-118.

Mission Duration: 12 days, 17 hours, 55 minutes.

Altitude: 122 nautical miles.

Primary Payload: 22nd station flight (13A.1), S5 Truss.

Dave Williams was a mission specialist on STS-118, the 22nd flight to the ISS and the 20th flight for *Endeavour*. During the mission, the crew successfully added truss segment S5, a new gyroscope and an external stowage platform to the ISS.

Show the cadets Figure 15G-2.

The mission successfully activated a new system that enables docked shuttles to draw electrical power from the ISS to extend visits to the outpost. Williams took part in three of the four spacewalks – the highest number of spacewalks performed in a single mission. He spent 17 hours and 47 minutes outside – a Canadian record. *Endeavour* carried 2 280 kg of equipment and supplies to the station and returned to earth with 1 800 kilograms of hardware and used equipment. Travelling 8.5 million km in space, the STS-118 mission was completed in 12 days, 17 hours, 55 minutes, and 34 seconds.

PLACE AND DATE OF BIRTH

Born May 16, 1954, in Saskatoon, Sask.

EDUCATION

Dave Williams' education includes:

- High school in Beaconsfield, Que.,
- BSc (Biology) from McGill University,
- MSc (Physiology) from McGill University,
- Doctorate of Medicine from the Faculty of Medicine, McGill University,
- Master of Surgery from the Faculty of Medicine, McGill University, and
- Completed a residency in family practice in the Faculty of Medicine, University of Ottawa.

PROFESSIONAL EXPERIENCE

Dave Williams pursued postgraduate studies in advanced invertebrate physiology at the Friday Harbour Laboratories at the University of Washington, Seattle, but his interests shifted to vertebrate neurophysiology when, for his master's thesis, he became involved in basic science research on how adrenal steroid hormones modify the regulation of sleep-wake cycles. While working in the Neurophysiological Laboratories at the Allan Memorial Institute for Psychiatry, Williams assisted in clinical studies of slow wave potentials within the central nervous system.

Williams served as an emergency physician with the Emergency Associates of Kitchener-Waterloo and as the medical director of the Westmount Urgent Care Clinic. Subsequently, he became the director of the Department of Emergency Services at Sunnybrook Health Science Centre and assistant professor of Surgery at the University of Toronto.

In June 1992, the CSA selected Williams as one of four successful candidates from a field of 5 330 applicants to begin astronaut training. He completed basic training and, in May 1993, was appointed manager of the Missions and Space Medicine Group within the Canadian Astronaut Program. His assignments included supervising the implementation of operational space medicine activities for the Canadian Astronaut Program Space Unit Life Simulation (CAPSULS) Project.

In January 1995, Williams was selected to join the international class of NASA mission specialist astronaut candidates. He reported to the Johnson Space Center (JSC) in March 1995, for a year of training and evaluation. Following the successful completion of this training in May 1996, he was assigned to the Payloads and Habitability Branch of the NASA Astronaut Office.

From July 1998, until September 2002, Dave Williams held the position of Director of the Space and Life Sciences Directorate at the Johnson Space Center in Houston, Texas. With this appointment, he became the first non-American to hold a senior management position within NASA. He concurrently held a six-month position as the first deputy associated administrator for crew health and safety in the Office of Space Flight at NASA Headquarters in 2001.

In addition to these assignments, Dave Williams continued to take part in astronaut training to maintain and further develop his skills. In October 2001, he became an aquanaut through his participation in the joint NASA-NOAA (National Oceanic and Atmospheric Administration) NEEMO 1 mission, a training exercise held in Aquarius, the world's only underwater research laboratory located 5.6 km off the shores of Key Largo, Florida. During this seven-day exercise, Williams became the first Canadian to have lived and worked in space and in the ocean.

In 2006, Dave Williams took the lead of NEEMO 9 as the crew commander of this mission, dedicated to assess new ways to deliver medical care to a remote location, as in a long space flight.

SPECIAL HONOURS

Dave Williams' special honours include:

- Academic awards:
    - recipient of the A.S. Hill Bursary, McGill University (1980),
    - recipient of the Walter Hoare Bursary, McGill University (1981),
    - recipient of the J.W. McConnell Award, McGill University (1981 to 1983),
    - Faculty Scholar (1982), Faculty of Medicine, McGill University,
    - University Scholar (1983), Faculty of Medicine, McGill University,
    - recipient of the Psychiatry Prize, Wood Gold Medal,
    - Dean's Honour List, Physiology Department, McGill University (1983), and
    - recipient of Second prize (1986, 1987, 1988) for participation in the University of Toronto Emergency Medicine Research Papers Program;
- recipient of the Commonwealth Certificate of Thanks and the Commonwealth Recognition Award for contributions to the Royal Life Saving Society of Canada,
- recipient of the NASA Space Flight Medal,
- recipient of the Melbourne W. Boynton Award, American Astronautical Society (1999),
- recipient of the Ramon y Cajal Institute of Neurobiology, Spanish Council for Scientific Research (CSIC) Bronze Medal for contribution to neuroscience during Mission STS-90 (1999),
- recipient of the Rotary National Award for Space Achievement (2000),
- recipient of the NASA Outstanding Leadership Medal (2002),
- Patron of the International Life Saving Federation (2002),
- Spokesperson for the Life Saving Society Canada,
- Honorary Ambassador of the SmartRisk Foundation,
- NASA JSC Space and Life Sciences Directorate Special Professional Achievement Award (2003) for the implementation of the Automatic External Defibrillator Program that has saved several lives at the NASA Johnson Space Center, and
- Honorary Doctor of Laws, University of Saskatchewan (2004).

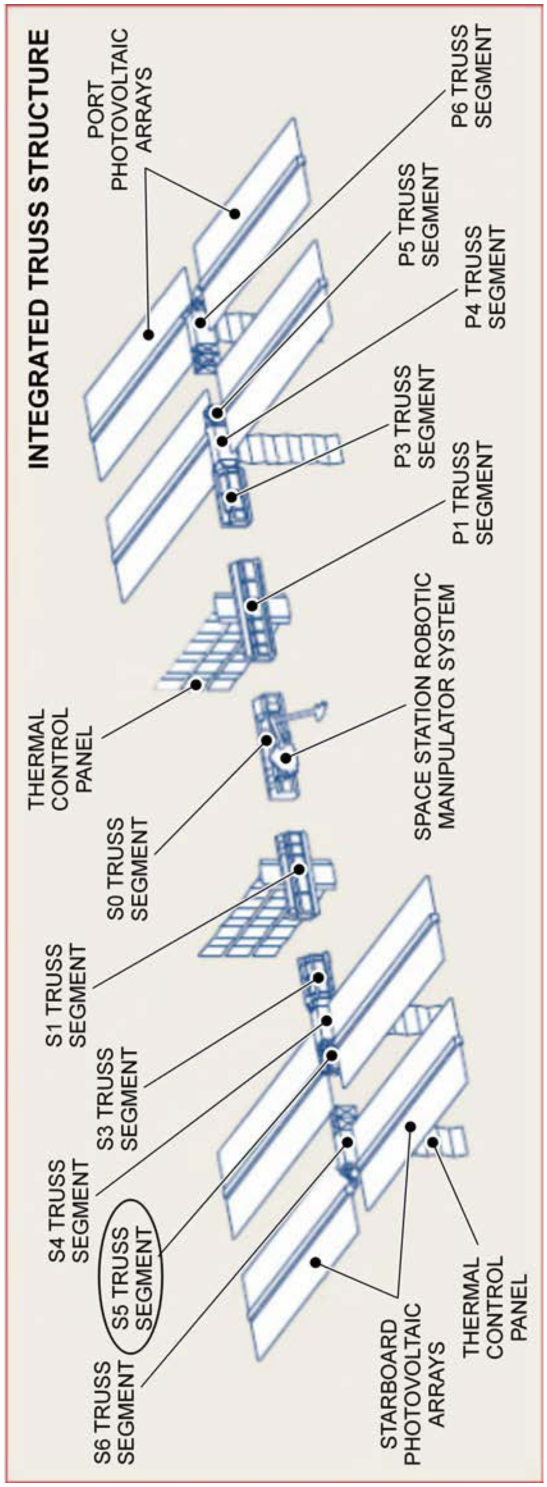
AFFILIATIONS

Dave Williams’ affiliations include:

- Member of the College of Physicians of Ontario,
- Member of Ontario Medical Association,
- Member of the Canadian Association of Emergency Physicians,
- Member of the Undersea and Hyperbaric Medicine Society, and
- Member of the Aerospace Medical Association.

Past affiliations include:

- Society for Neuroscience,
- New York Academy of Science, and
- Montreal Physiological Society.



Canadian Space Agency, 2007, Missions: STS-118 Mission Overview. Retrieved March 2, 2008, from http://www.space.gc.ca/asc/eng/missions/sts-118/overview.asp

Figure 15G-2 Integrated Truss S5

ASTRONAUT JULIE PAYETTE

Canadian Space Agency, 2008, Astronauts: Julie Payette Biography. Retrieved March 2, 2008, from http://www.space.gc.ca/asc/eng/astronauts/biopayette.asp

Figure 15H-1 Astronaut Julie Payette

ASTRONAUT JULIE PAYETTE

Julie Payette enjoys running, skiing, racquet sports and scuba diving. She has a commercial pilot licence with float rating. Fluent in French and English, she can converse in Spanish, Italian, Russian and German. She plays the piano and has sung with the Orchestre symphonique de Montréal, the Piacere Vocale in Basel, Switzerland and the Tafelmusik Baroque Orchestra in Toronto. She is married and has two children.

MISSIONS

STS-96

Mission: Second International Space Station Flight.

Space Shuttle: Discovery.

Launched: May 27, 1999, 6:49:42 a.m. EDT.

Landed: June 6, 1999, 2:02:43 a.m. EDT.

Mission Duration: 10 days.

Orbit Altitude: 173 nautical miles.

Mission Highlights

All major objectives were accomplished during the mission. On May 29th, *Discovery* made the first docking to the ISS as it flew over the Russian-Kazakh border.

The 45th space walk in space shuttle history and the fourth of the ISS era took place during this mission. Astronauts transferred a US-built crane called the orbital transfer device and parts of the Russian crane Strela from the shuttle's payload bay and attached them to locations on the outside of the station. The astronauts also installed two new portable foot restraints, which will fit both American and Russian space boots, and they attached three bags filled with tools and handrails for use during future assembly operations.

The crew transferred 3 567 pounds of material, including clothing, sleeping bags, spare parts, medical equipment, supplies, hardware and about 84 gallons of water, to the interior of the station. The astronauts also installed parts of a wireless strain gauge system to help engineers track the effects of adding modules to the station throughout its assembly.

The astronauts spent a total of 79 hours, 30 minutes inside the station. Before departure, a series of 17 pulses of Discovery's reaction control system jets boosted the station to an orbit of approximately 246 statute miles. After spending 5 days, 18 hours and 17 minutes linked to the station, *Discovery* undocked at 6:39 p.m. EDT. Discovery's jets fired to move to a distance of about 400 feet for a 2-1/2 lap fly-around during which the crew made a detailed photographic record of the ISS.

After the fly-around, mission specialist Julie Payette deployed the Starshine satellite from the orbiter's cargo bay. The spherical, reflective object entered an orbit two miles below *Discovery*. The small probe became instantly visible from Earth as part of a project allowing more than 25 000 students from 18 countries to track its progress. Other payloads included the Shuttle Vibration Forces experiment and the Integrated Vehicle Health Monitoring for the Human Exploration and Development of Space (HEDS) Technology Demonstration.

PLACE AND DATE OF BIRTH

Born October 20, 1963, in Montréal, Que.

EDUCATION

Julie Payette's education includes:

- primary and secondary school in Montréal, Que.,

- International Baccalaureate from United World College of the Atlantic in Wales, UK,
- Bachelor of Engineering, Electrical cum laude from McGill University, Montréal, and
- Master of Applied Science, Computer Engineering, from the University of Toronto.

PROFESSIONAL EXPERIENCE

Before joining the space program, Julie Payette conducted research in computer systems, natural language processing and automatic speech recognition.

Her previous employment included:

- system engineer with IBM Canada (1986–1988),
- research assistant at the University of Toronto (1988–1990),
- visiting scientist at the IBM Research Laboratory, in Zurich, Switzerland (1991),
- research engineer with BNR/Northern in Montréal (1992), and
- in June 1992, the Canadian Space Agency selected Ms. Payette from 5 330 applicants to become one of four astronauts.

After her basic training in Canada, she worked as a technical advisor for the Mobile Servicing System (MSS Canadarm2), an advanced robotics system contributed by Canada to the ISS. In preparation for a space mission assignment, Payette obtained her commercial pilot license, studied Russian and logged 120 hours as a research operator on board reduced gravity aircraft. In April 1996, Payette was certified as a one-atmosphere, deep-sea diving suit operator. Payette obtained her military pilot captaincy on the CT-114 Tutor jet at the Canadian Forces Base in Moose Jaw, Sask. in February 1996. She obtained her military instrument rating in 1997. She has logged more than 1 200 hours of flight time.

Payette reported to the NASA Johnson Space Center in Houston, Texas in August 1996. She completed initial astronaut training in April 1998 and was assigned to work on technical issues in robotics for the Astronaut Office. In the spring of 1999, she visited the ISS aboard STS-96.

From September 1999, to December 2002, Payette was assigned to represent the astronaut corps at the European and Russian space agencies where she supervised procedure development, equipment verification and space hardware processing for the ISS Program.

After January 2003, Payette worked as a CapCom (Spacecraft Communicator) at Mission Control Center in Houston and was Lead CapCom for Space Shuttle mission STS-121 in 2006. The CapCom is responsible for all communications between ground controllers and the astronauts in flight.

SPECIAL HONOURS

Julie Payette’s special honours include:

- recipient of a scholarship to attend the Atlantic College in Wales, UK,
- recipient of a Greville-Smith Scholarship (highest undergraduate award at McGill University),
- McGill University Faculty Scholar (1983–1986),
- recipient of a Natural Sciences and Engineering Research Council of Canada (NSERC) Scholarship,
- recipient of a Massey College Fellowship,
- recipient of the Canadian Council of Professional Engineers Exceptional Achievement Award,
- recipient of the Chevalier de l’Ordre de la Pléiade de la francophonie,
- Ordre national du Québec,

- recipient of honorary Degrees from:
  - Queen’s University,
  - University of Ottawa,
  - Simon Fraser University,
  - Université Laval,
  - University of Regina,
  - Royal Roads University,
  - University of Toronto,
  - University of Victoria,
  - Nipissing University,
  - McGill University,
  - Mount Saint Vincent University,
  - McMaster University,
  - University of Lethbridge,
  - Mount Allison University, and
  - University of Alberta.

AFFILIATIONS

Julie Payette’s affiliations include:

- Member of l’Ordre des Ingénieurs du Québec,
- Fellow of the Canadian Academy of Engineering,
- Queen’s University Board of Directors,
- Former Governor-in-Council for NSERC, and
- Les Amies d’affaires du Ritz.

EARLY MANNED SPACE EXPLORATION TIMELINE

MERCURY PROGRAM

- October 1, 1958 National Aeronautics and Space Administration (NASA) created
- November 26, 1958 Mercury program announced
- December 4, 1959 Launch of Sam (a monkey) on Little Joe 2
- April 9, 1959 NASA names the seven Mercury astronauts
- January 21, 1960 Launch of Miss Sam (a monkey) on Little Joe IB
- January 31, 1961 Launch of Ham (a chimpanzee) on Mercury Redstone 2
- **May 5, 1961 Launch of Alan Shepard in Freedom 7 (suborbital)**
- July 21, 1961 Launch of Gus Grissom in Liberty 7 (suborbital)
- November 29, 1961 Launch of Enos (a chimpanzee) on Mercury Atlas 5 (orbital)
- January 3, 1962 Gemini program formally conceived
- **February 20, 1962 Launch of John Glenn in Friendship 7, first American human orbital flight**
- May 24, 1962 Launch of Scott Carpenter in Aurora 7
- October 3, 1962 Launch of Walter Schirra in Sigma 7
- May 15, 1963 Launch of Gordon Cooper in Faith 7, the final Mercury mission

GEMINI PROGRAM

- March 23, 1965. Gemini III. First manned Gemini flight completed three orbits
- June 03–07, 1965. Gemini IV. First American Extra Vehicular Activity (EVA)
- August 21–29, 1965. Gemini V. First use of fuel cells for electrical power
- **December 04, 1965.** Gemini VII**. First rendezvous in space, with Gemini VI-A**
- December 15, 1965. Gemini VI-A. First rendezvous in space, with Gemini VII
- **March 16, 1966.** Gemini VIII**. First docking with another (unmanned) spacecraft**
- June 03–06, 1966. Gemini IX-A. Three rendezvous and two hours of EVA
- July 18–21, 1966. Gemini X. Rendezvoused with target vehicle and EVA
- September 12, 1966. Gemini XI. Gemini record altitude of 1 189.3 km
- November 11, 1966. Gemini XII. Final Gemini flight: rendezvous, docking, EVA

APOLLO PROGRAM

- October, 1968 Apollo 7. Earth orbit
- **December,1968 Apollo 8. Ten lunar orbits**
- March, 1969 Apollo 9. First manned flight of lunar module
- May, 1969 Apollo 10. Dress rehearsal for Moon landing
- **July 20, 1969 Apollo 11. First lunar landing mission (on the Sea of Tranquility)**
- November, 1969 Apollo 12. Second lunar landing (on the Ocean of Storms)

- April, 1970 Apollo 13. Mission aborted after an on-board explosion
- January, 1971 Apollo 14. Third lunar landing (at Fra Mauro)
- July, 1971 Apollo 15. Fourth lunar landing (in the Hadley Apennine region)
- April, 1972 Apollo 16. Fifth lunar landing (on the Descartes highlands)
- December, 1972 Apollo 17. Last lunar landing (on theTaurus Littrow highlands)

NASA 40th Anniversary of the Mercury 7, by T. Gray, 2001. Retrieved March 5, 2008, from http://history.nasa.gov/40thmerc7/shepard.htm

Figure 15I-1 Alan B. Shepard

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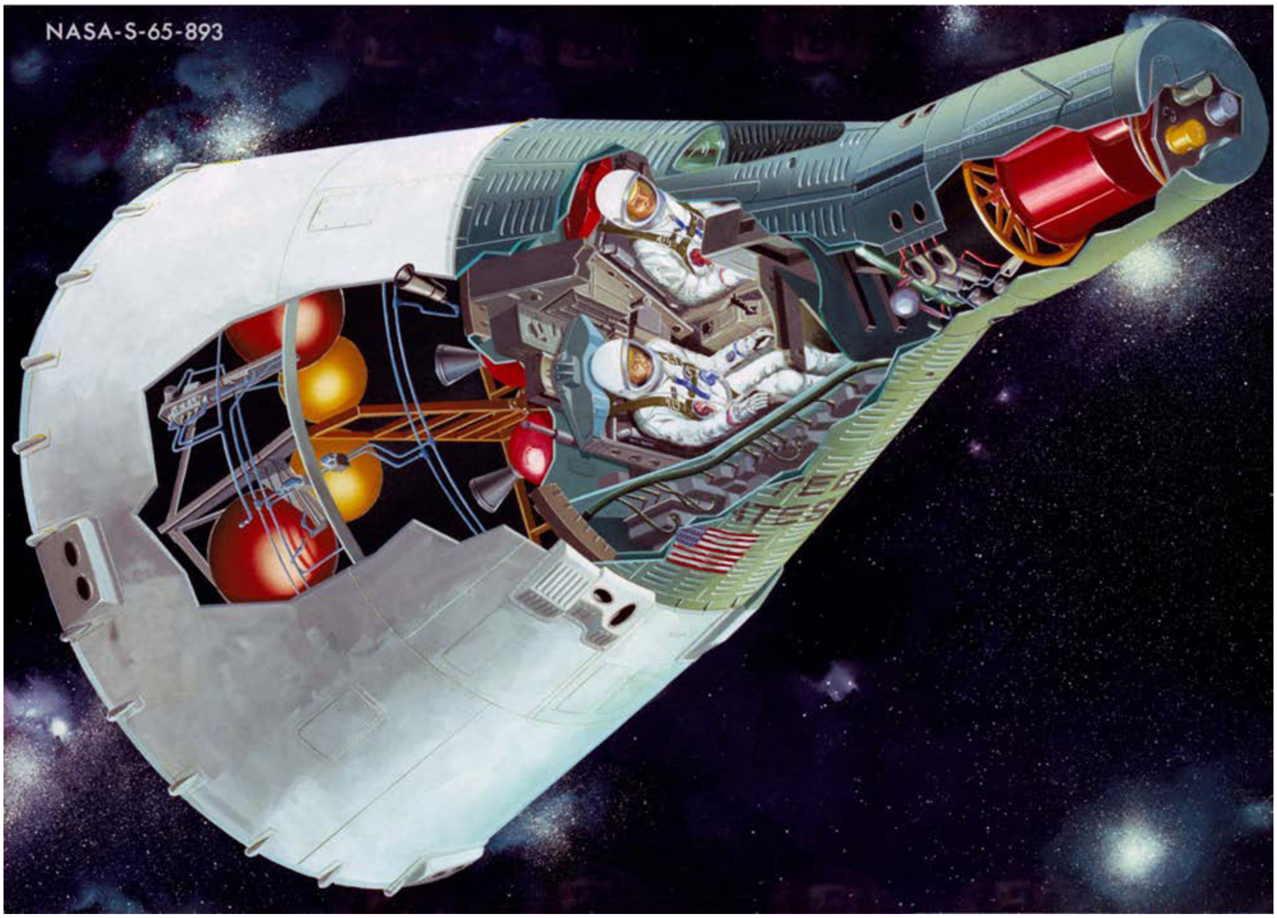
GEMINI PROGRAM

"Friendship 7: Biographies", by C. Gainor, 2007, James A. Chamberlin. Retrieved December 1, 2007, from http://history.nasa.gov/friendship7/pages/bios.html

Figure 15J-1 James A. Chamberlin



NASA Gemini: Stepping Stone to the Moon--40 Years Later. Retrieved March 5, 2008, from http://www.nasa.gov/mission_pages/gemini/index.html

Figure 15J-2 Gemini Capsule Cutaway

NASA Gemini: Stepping Stone to the Moon--40 Years Later. Retrieved March 5, 2008, from http://www.nasa.gov/mission_pages/gemini/index.html

Figure 15J-3 Gemini VII Seen From Gemini VI-A

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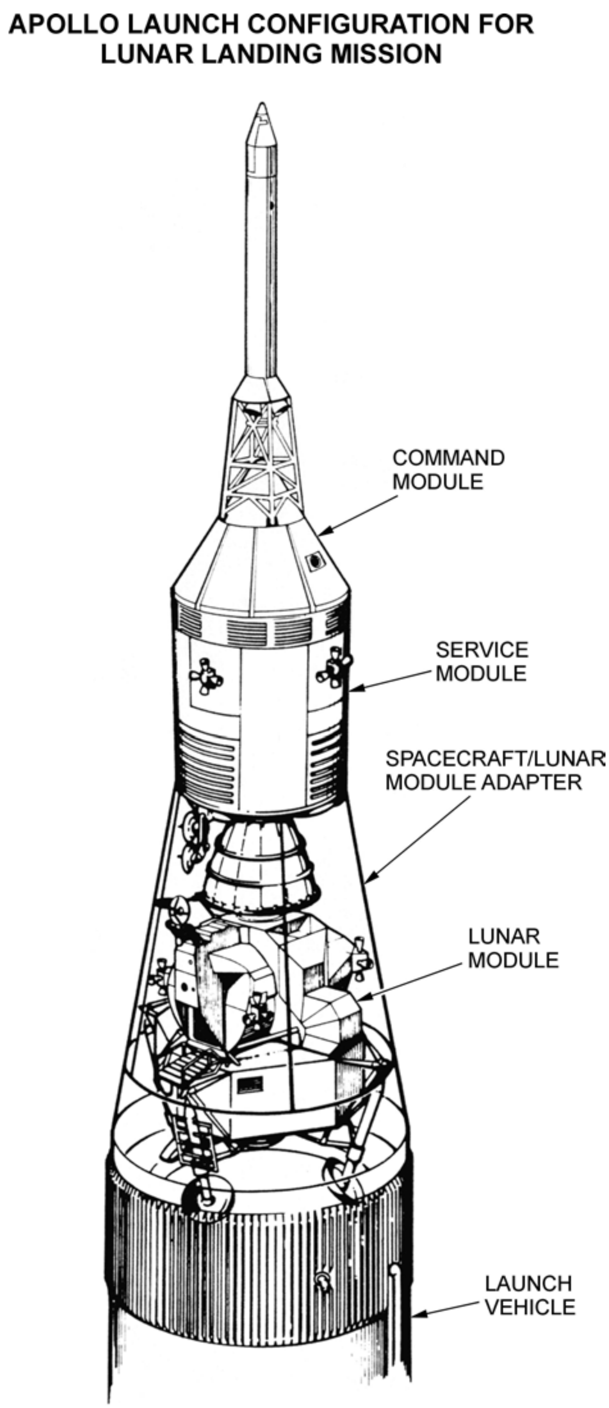
APOLLO PROGRAM

"Great Images in NASA", 2002, GPN-2000-000629. Retrieved December 1, 2007, from http://grin.hq.nasa.gov/ABSTRACTS/GPN-2000-001053.html

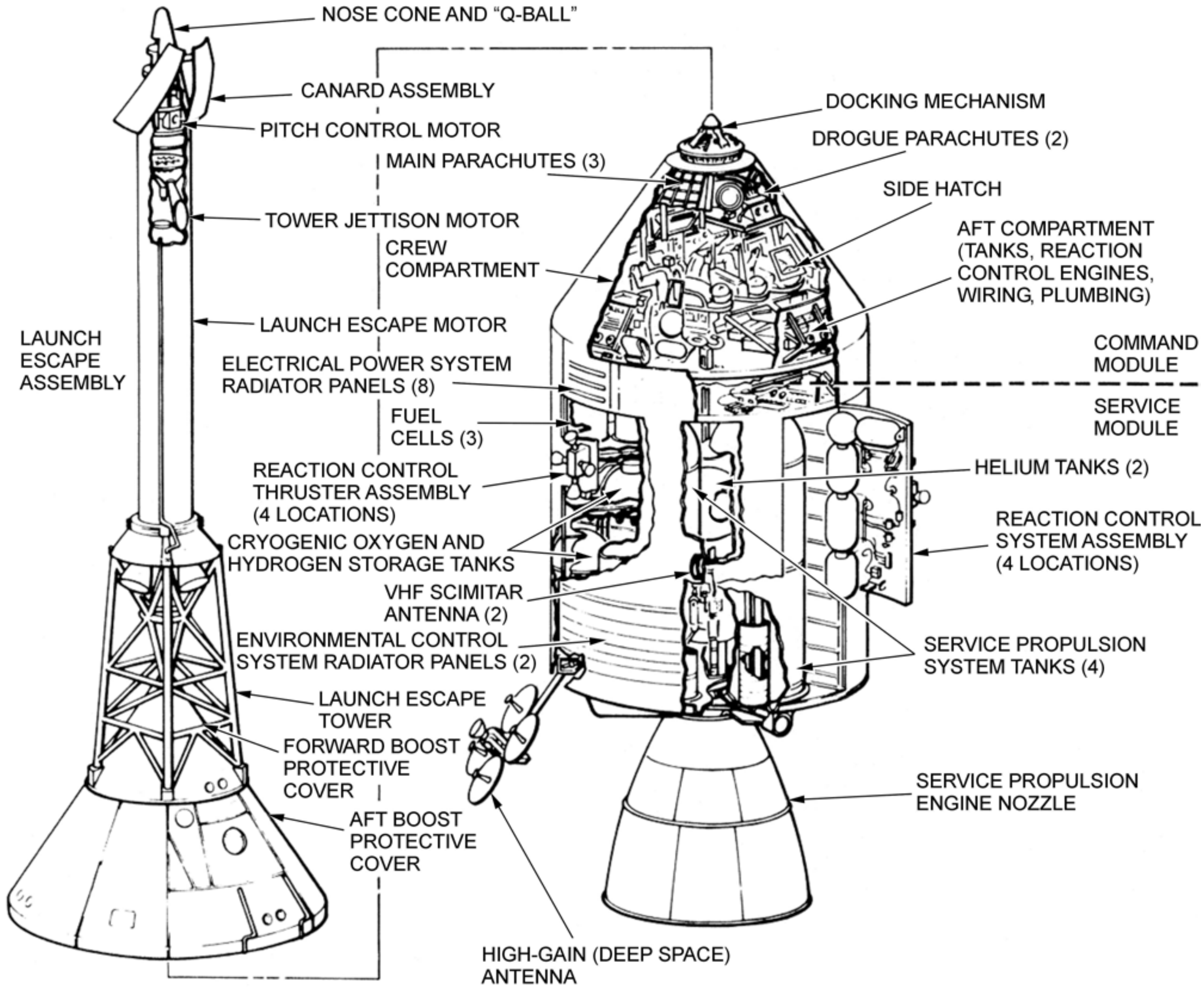
Figure 15K-1 Launching Apollo 11



Project Apollo Drawings and Technical Diagrams, NASA History Division, 2007. Retrieved March 5, 2008, from http://www.hq.nasa.gov/office/pao/History/diagrams/apollo.html

Figure 15K-2 In the Nose Cone

APOLLO COMMAND AND SERVICE MODULES AND LAUNCH ESCAPE SYSTEM



Project Apollo Drawings and Technical Diagrams, NASA History Division, 2007. Retrieved March 5, 2008, from http://www.hq.nasa.gov/office/pao/History/diagrams/apollo.html

Figure 15K-3 Modules Revealed

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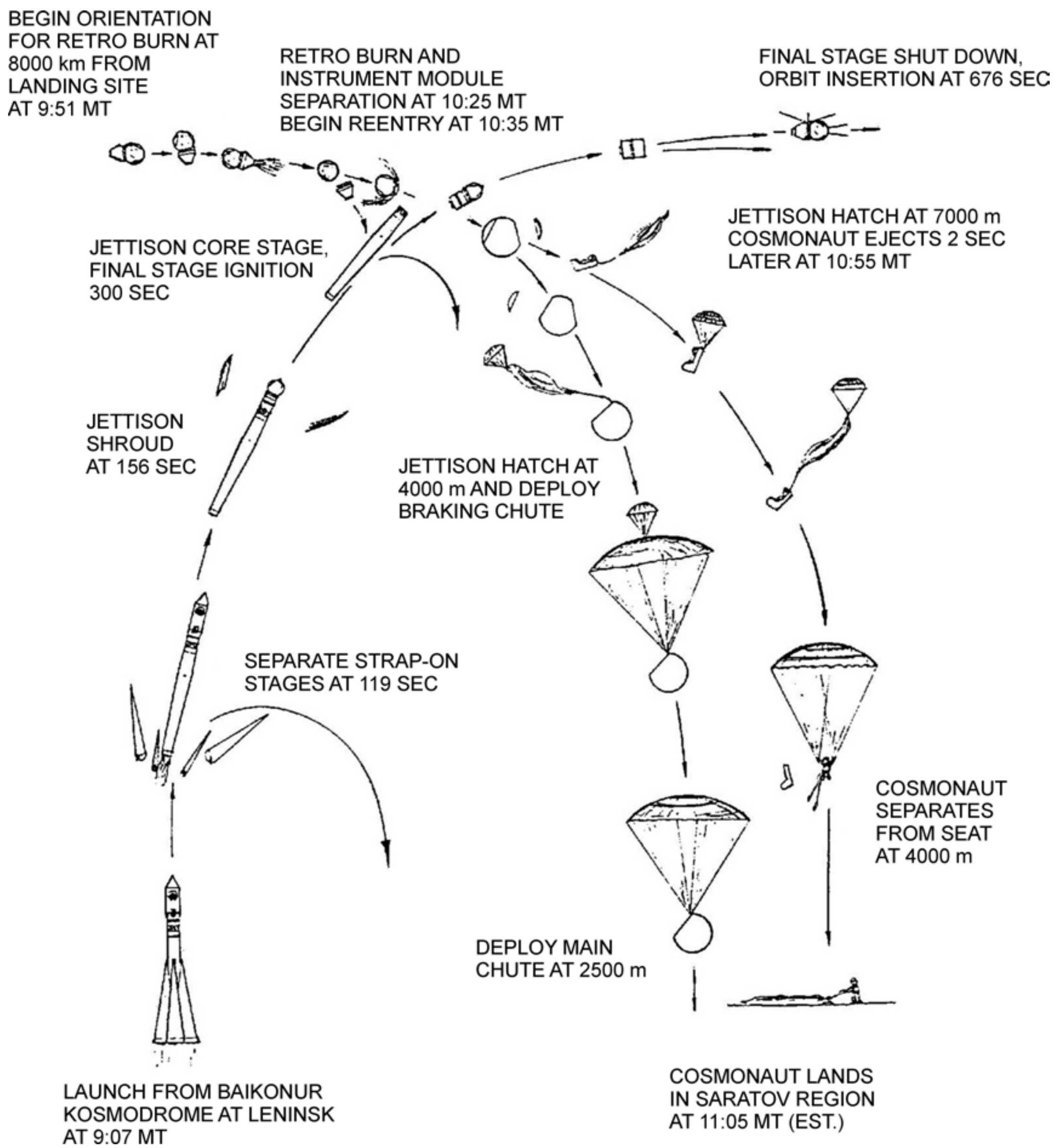
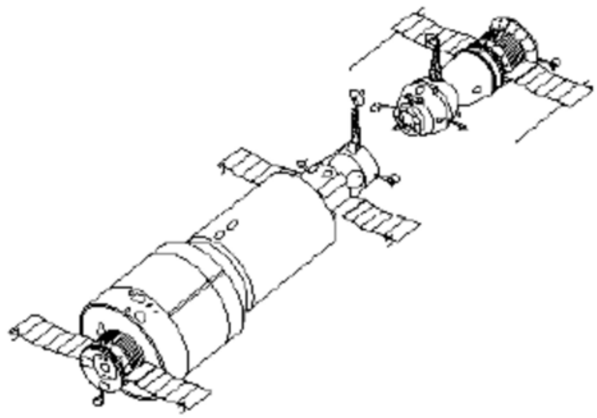
VOSTOK PROGRAM



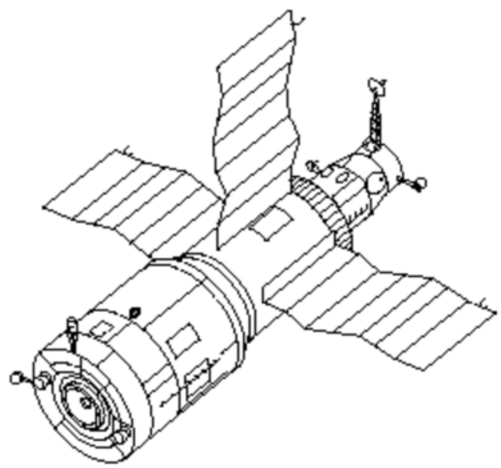
"Great Images in NASA", 2002, GPN-2002-000224. Retrieved December 1, 2007, from http://grin.hq.nasa.gov/ABSTRACTS/GPN-2000-001053.html

Figure 15L-1 Vostok-1 Historic First Manned Spacefight



"NASA Facts", 1997, International Space Station: Russian Space Stations. Retrieved December 1, 2007, from http://spaceflight.nasa.gov/history/shuttle-mir/spacecraft/to-s-mir.htm

Figure 15L-2 Salyut-1 Station With a Soyuz About to Dock

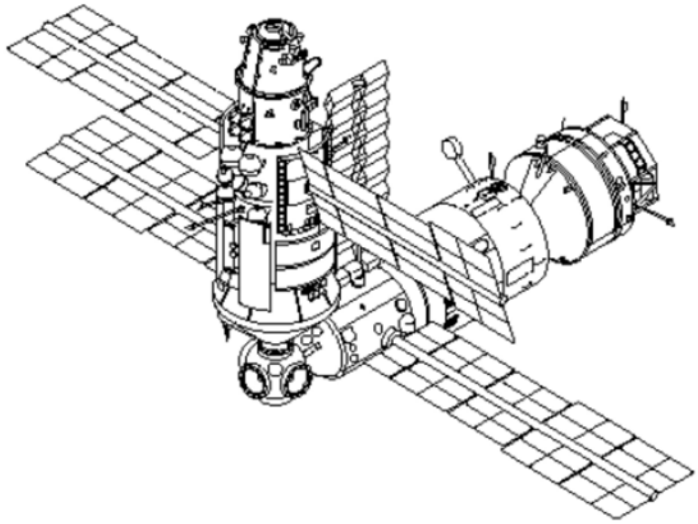


"NASA Facts", 1997, International Space Station: Russian Space Stations. Retrieved December 1, 2007, from http://spaceflight.nasa.gov/history/shuttle-mir/spacecraft/to-s-mir.htm

Figure 15L-3 Salyut-6 (1977–1982)

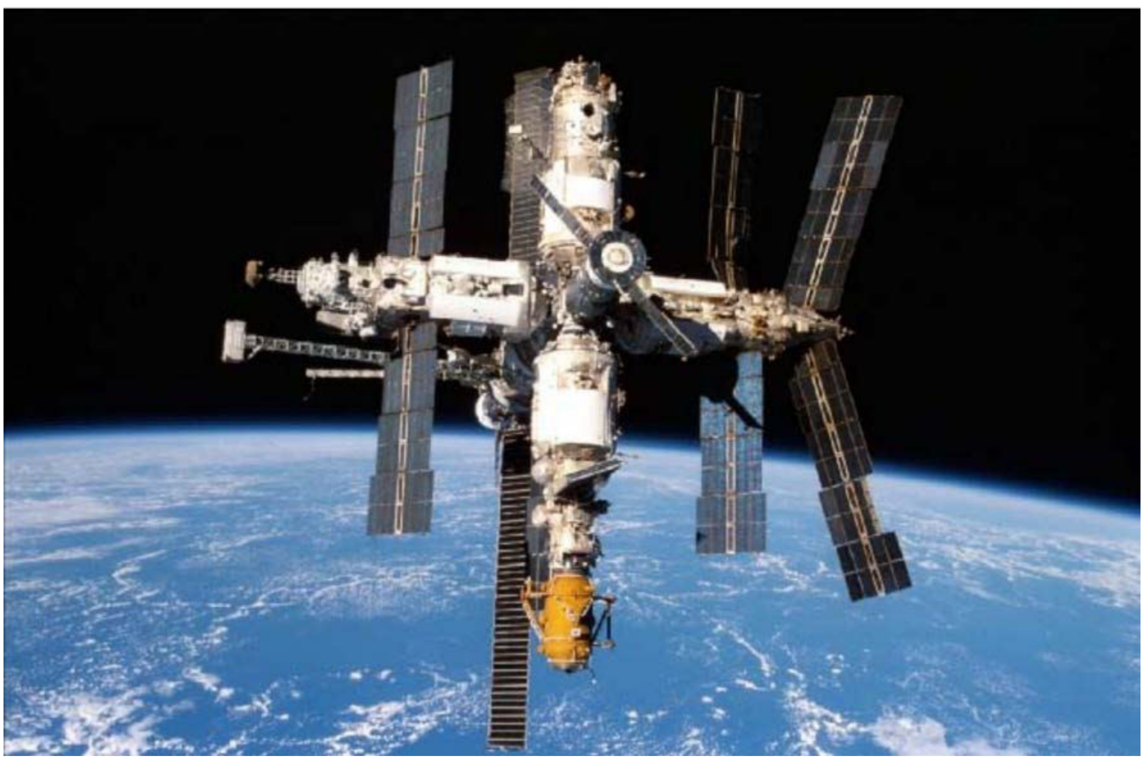
"Wikipedia", 2007, Salyut Program. Retrieved November 30, 2007, from http://en.wikipedia.org/wiki/Image:Salyut_7_from_Soyuz_T-13.jpg

Figure 15L-4 Salyut-7



"NASA Facts", 1997, International Space Station: Russian Space Stations. Retrieved December 1, 2007, from http://spaceflight.nasa.gov/history/shuttle-mir/spacecraft/to-s-mir.htm

Figure 15L-5 Mir Space Station



NASA "Multimedia Photo Gallery", 1998, STS 89. Retrieved December 2, 2007, from http://spaceflight.nasa.gov/history/shuttle-mir/spacecraft/s-mir.htm

Figure 15L-6 The Mir Space Station and Earth

CSA LOGO

Canadian Space Agency, 2008, Canadian Space Agency Logo. Retrieved April 14, 2008, from http://upload.wikimedia.org/wikipedia/en/0/01/Canadian_Space_Agency_logo.png

Figure 15M-1 CSA Logo

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OSM LOGO

Canadian Space Agency, 2008, Operational Space Medicine Logo. Retrieved April 14, 2008, from http://www.space.gc.ca/asc/eng/astronauts/osm_crest.asp

Figure 15N-1 OSM Logo

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CANADIAN SPACE PROGRAM

CANADA'S INVOLVEMENT IN SPACE TECHNOLOGIES

The CSA headquarters is located at the John H. Chapman Space Centre in Saint-Hubert, Que. Canada is involved in many aspects of space exploration. Canadian scientists and researchers are particularly interested with the development and testing of space technologies.

The David Florida Laboratory (DFL). The David Florida Laboratory is Canada's world-class spacecraft assembly, integration and testing centre.

The Canadian Analogue Research Network (CARN). CARN is the organization that uses Canadian sites for field studies. These analogue sites approximate conditions that may exist or have existed on Mars and other planetary bodies such as the moon and the Solar System's icy moons.

Partnerships With the Canadian Space Agency (CSA). The CSA has many partners including international space agencies, industry, post-secondary researchers and educational projects.

CSA MISSIONS

CSA has participated in many space missions with its partners. Canadian astronauts or Canadian technology has gone into space with agencies from the United States, Russia, Europe and Japan. There have been four basic types of CSA missions:

Telecommunications. Being able to keep all places in the country connected with advanced telecommunication services assists every Canadian in competing in the global marketplace.

Earth Observation. Canada's earth-observation initiatives enhance our understanding of the planet and its environment. By observing the earth from space, essential information on oceans, ice, land environments and the atmosphere is gathered.

Space Exploration. Canadian astronauts have been on many missions in various space shuttles. Canada is renowned for the exceptional instruments in its science satellites which collect data that will expand our understanding of the origin, formation, structure and evolution of celestial bodies and the universe.

Space Medicine. Space medicine combines many medical specialties to examine the effects of spaceflight on humans and prevent problems associated with living in a unique, isolated, and extreme environment like space.

For more information about the Canadian space program visit www.space.gc.ca.

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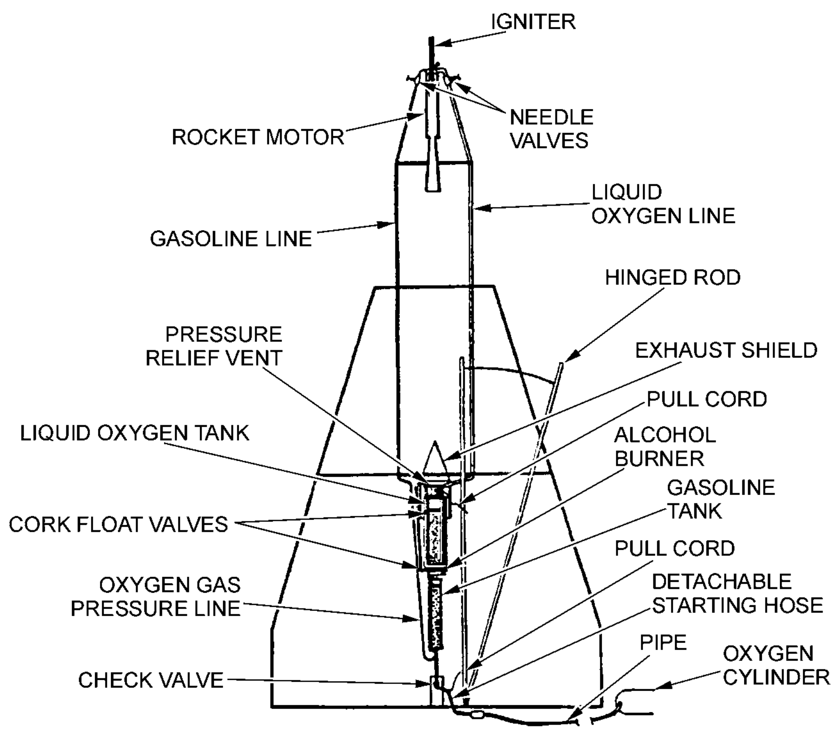
SPACE FLIGHT HISTORY

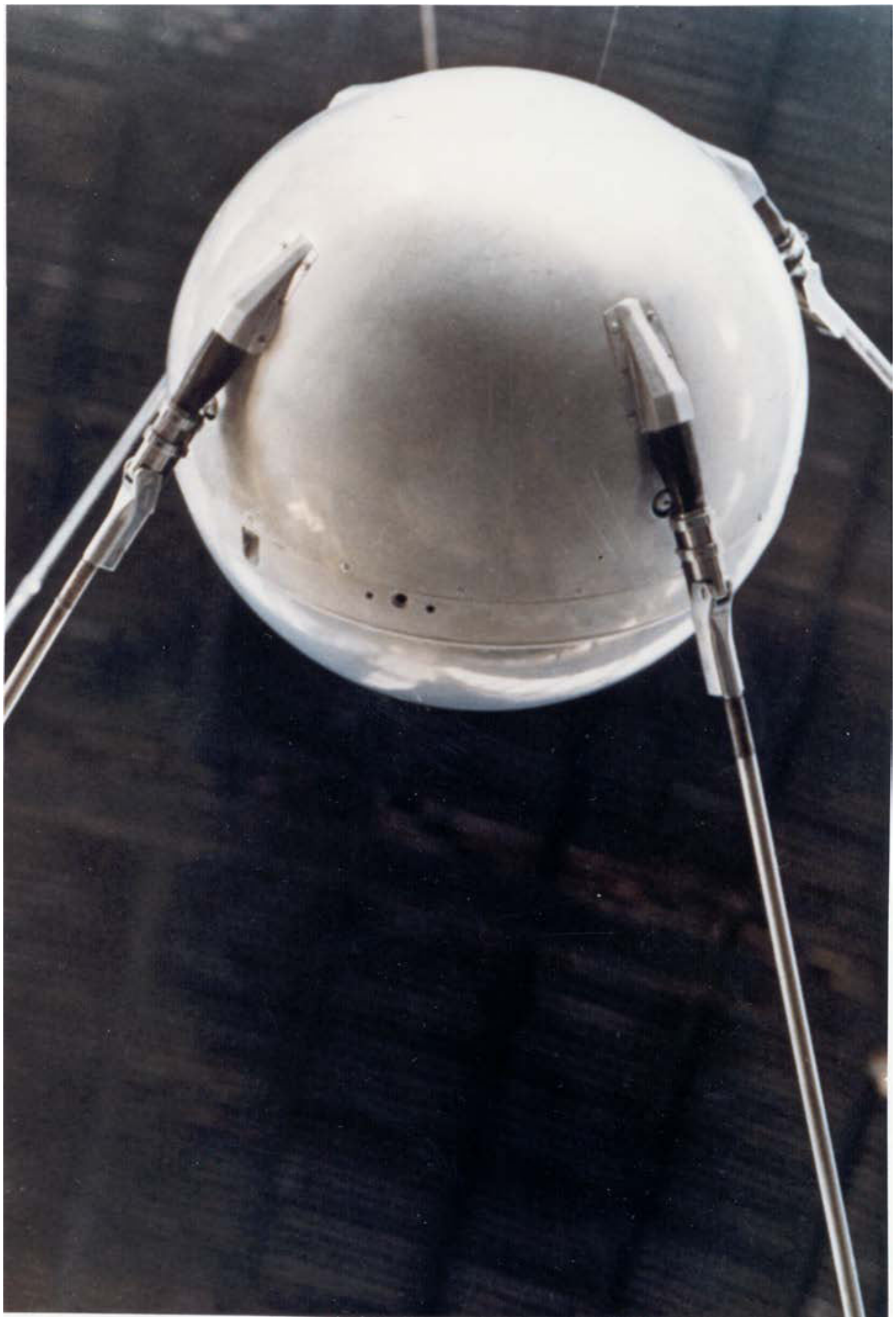
“A Beginner’s Guide to Rockets”, Rocket Gallery. Retrieved March 24, 2007, from http://exploration.grc.nasa.gov/education/rocket/gallery.html

Figure 15P-1 Dr. Robert Goddard, Father of Modern Rocketry



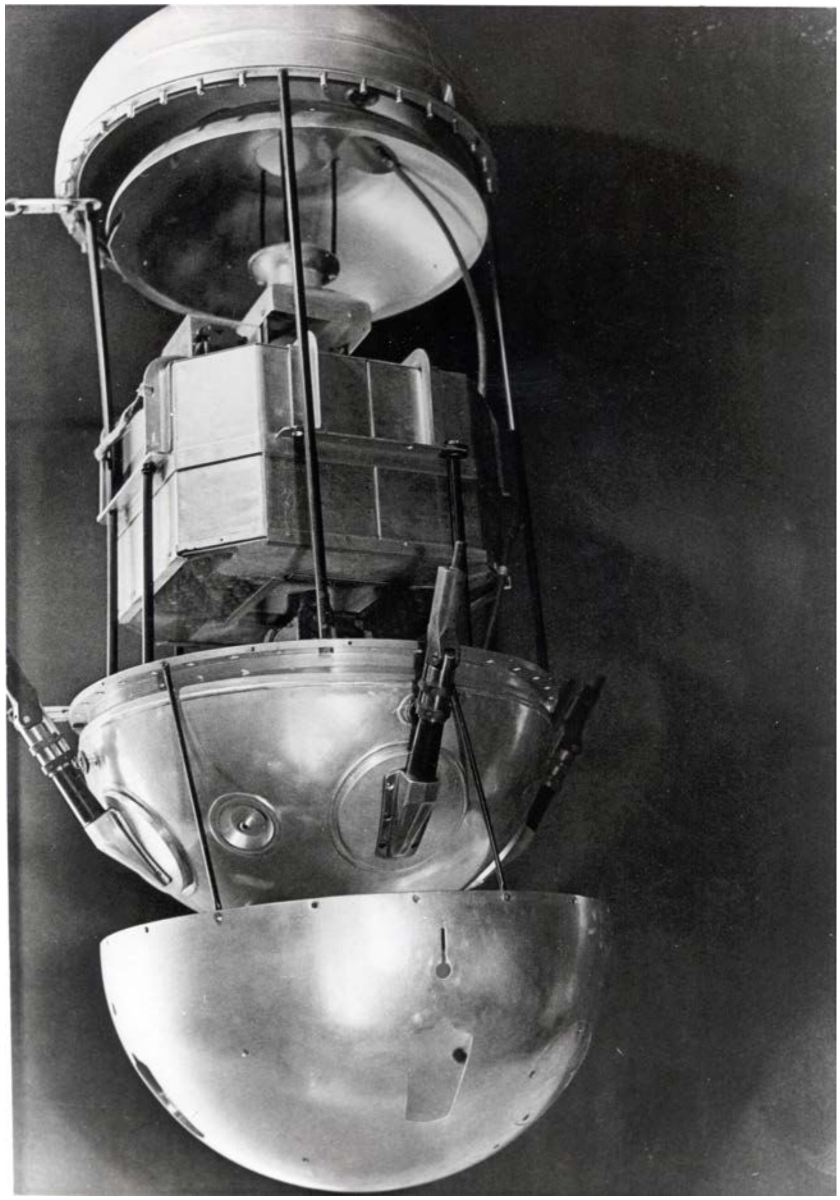
“Rockets”, A Brief History of Rockets. Retrieved March 24, 2007, from http://www.grc.nasa.gov/WWW/K-12/TRC/Rockets/history_of_rockets.html

Figure 15P-2 Goddard’s 1926 Rocket



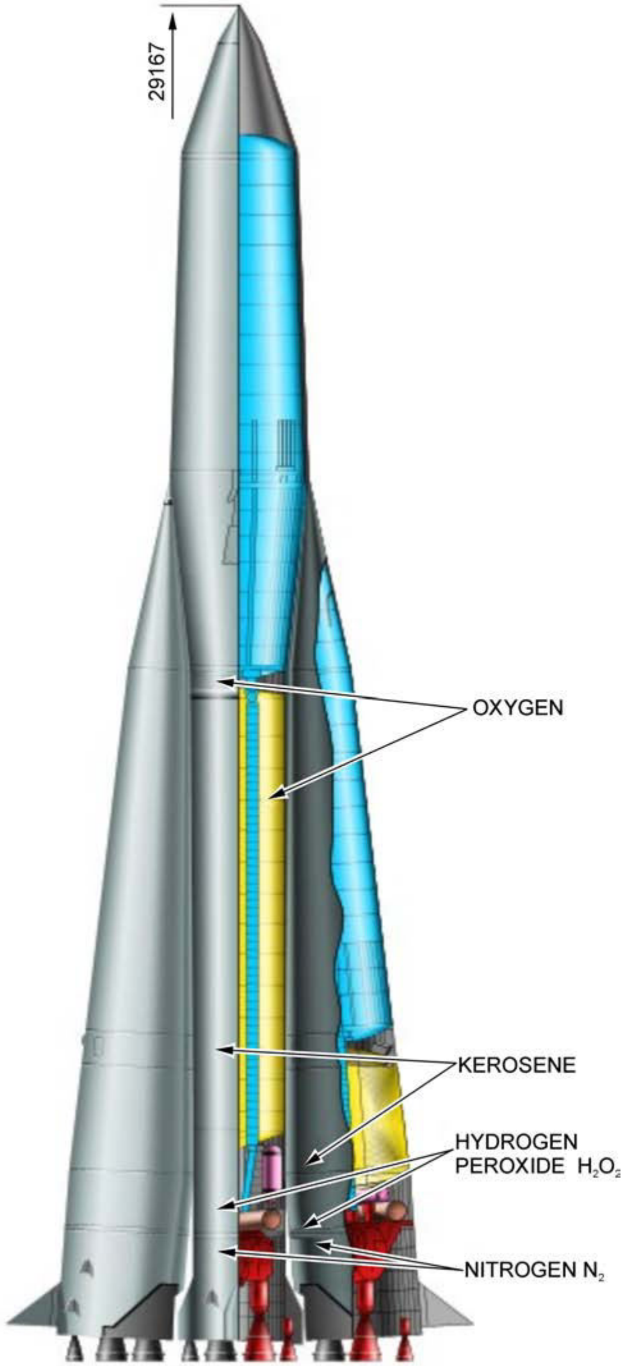
"Sputnik: The Fiftieth Anniversary", 2007, Photo Gallery. Retrieved November 29, 2007, from http://www.history.nasa.gov/sputnik/gallerysput.html

Figure 15P-3 Sputnik



"Sputnik: The Fiftieth Anniversary", 2007, Photo Gallery. Retrieved November 29, 2007, from http://www.history.nasa.gov/sputnik/gallerysput.html

Figure 15P-4 Sputnik Revealed



"Roscosmos", Space Programs Rocket Families R-7. Retrieved March 25, 2007, from http://www.roscosmos.ru/Roket1Show.asp?RoketID=8

Figure 15P-5 Sputnik's R-7 Rocket

"Russian Space Web", 2007, Rockets. Retrieved December 2, 2007, from http://www.russianspaceweb.com/r7.html

Figure 15P-6 Two-Stage R-7 Rocket Modified for Sputnik-1

Flight History JUPITER-C (three-stage configuration):

September 20, 1956: Lofted a payload to an altitude of 1 095 km and a range of 5 313 km from Cape Canaveral, Florida.

May 15, 1957: Lofted a nose cone to an altitude of 563 km and a range of 1 143 km.

August 8, 1957: Lofted a 1/3-scale Jupiter nose cone to an altitude of 459 km and a range of 2 141 km.

January 31, 1958: Orbited Explorer-1 satellite.

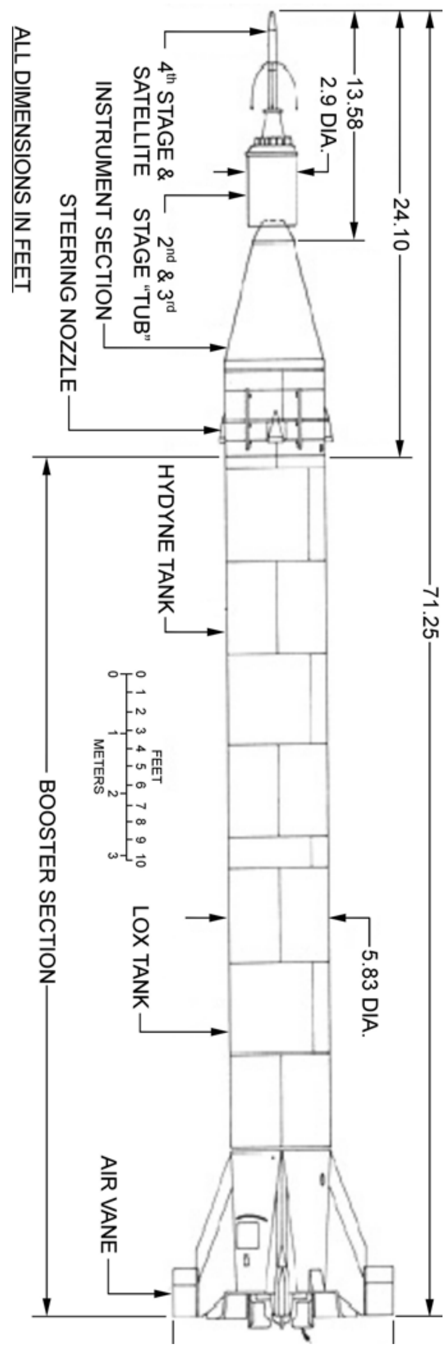
March 5, 1958: Attempted orbit of Explorer-II failed because fourth stage did not ignite.

March 26, 1958: Orbited Explorer-III satellite.

July 26,1958: Orbited Explorer-IV satellite.

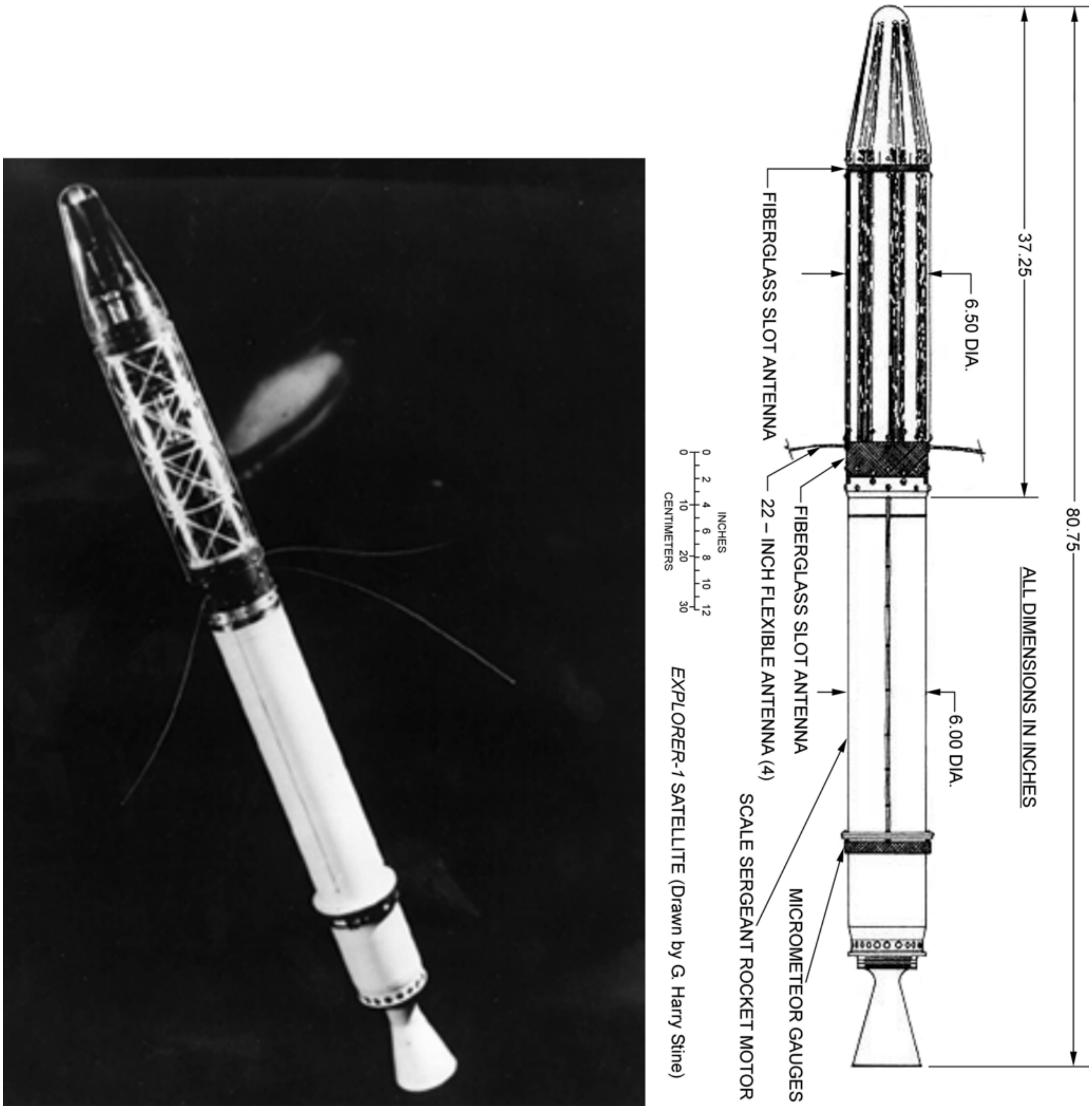
August 24,1958: Attempted orbit of Explorer-V satellite failed because booster collided with second stage after separation, causing the upper stage firing angle to be off.

October 23, 1958: Attempted orbit of inflatable Beacon satellite failed when second stage separated prematurely from booster.



"Sputnik: The Fiftieth Anniversary", Sputnik and The Dawn of the Space Age.
Retrieved March 25, 2007, from http://history.nasa.gov/sputnik/expinfo.html

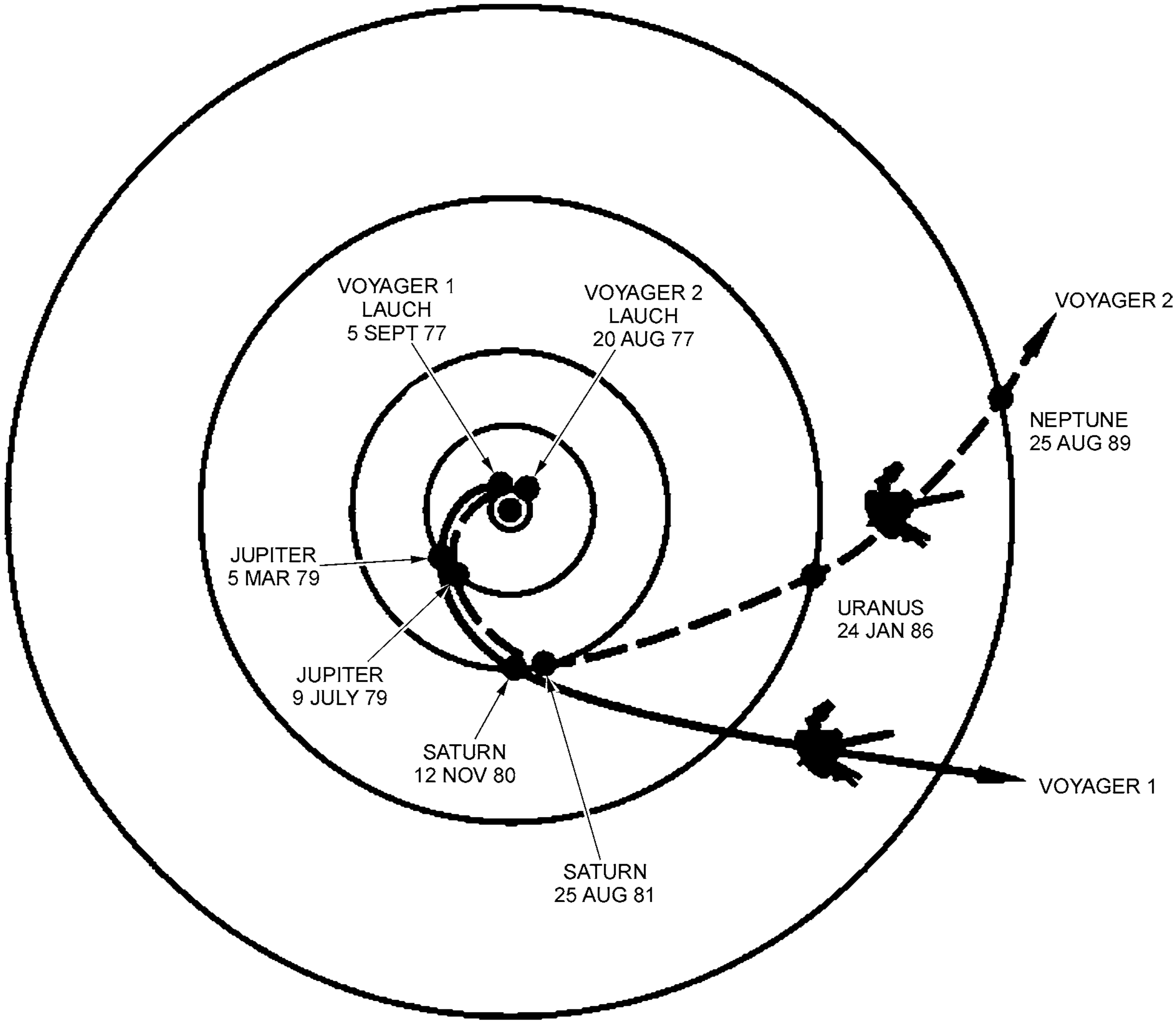
Figure 15P-7 Jupiter-C and Explorer 1



"Sputnik: The Fiftieth Anniversary", Sputnik and The Dawn of the Space Age. Retrieved March 25, 2007, from http://history.nasa.gov/sputnik/expinfo.html

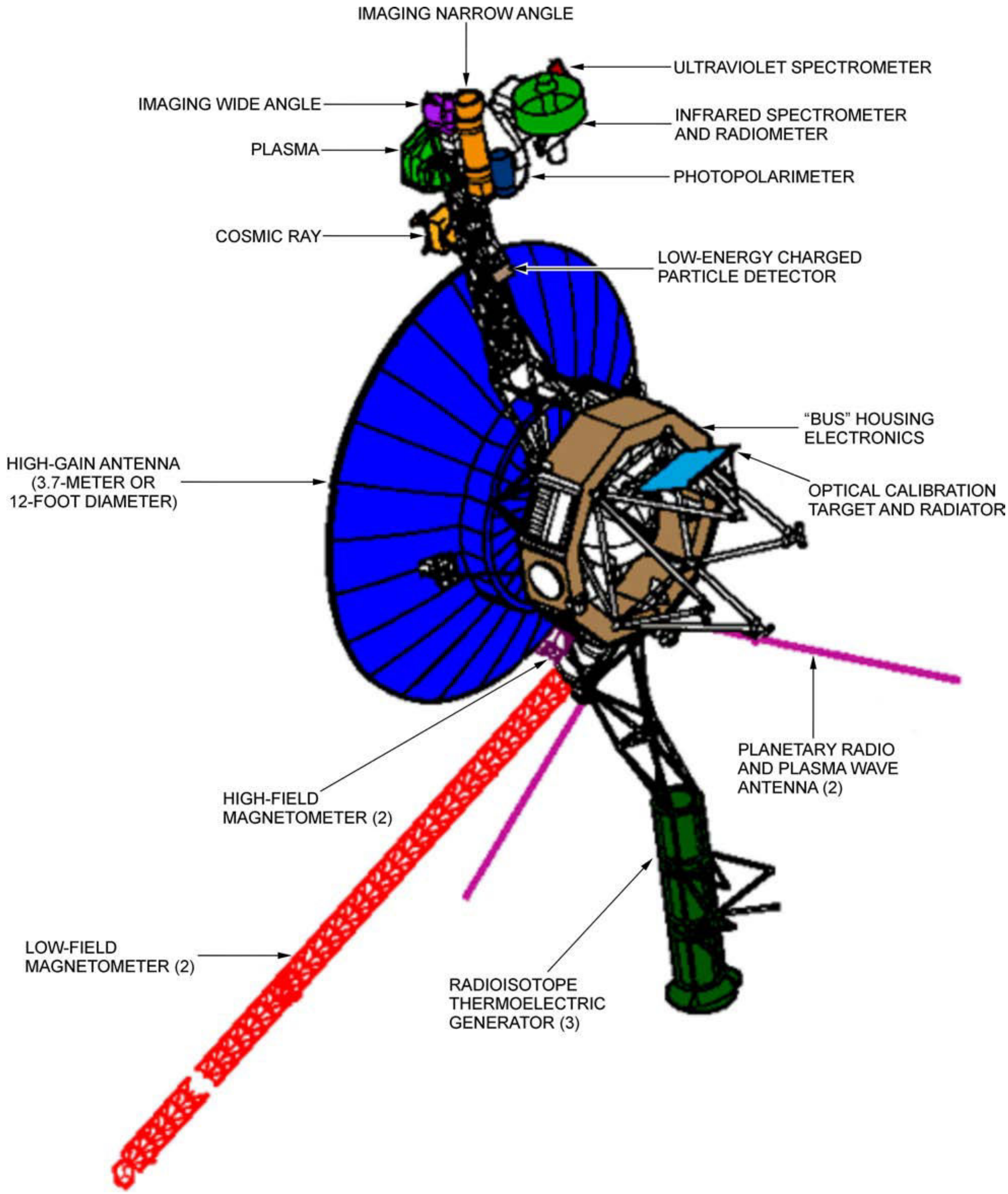
Figure 15P-8 Explorer 1

INTERSTELLAR MISSION



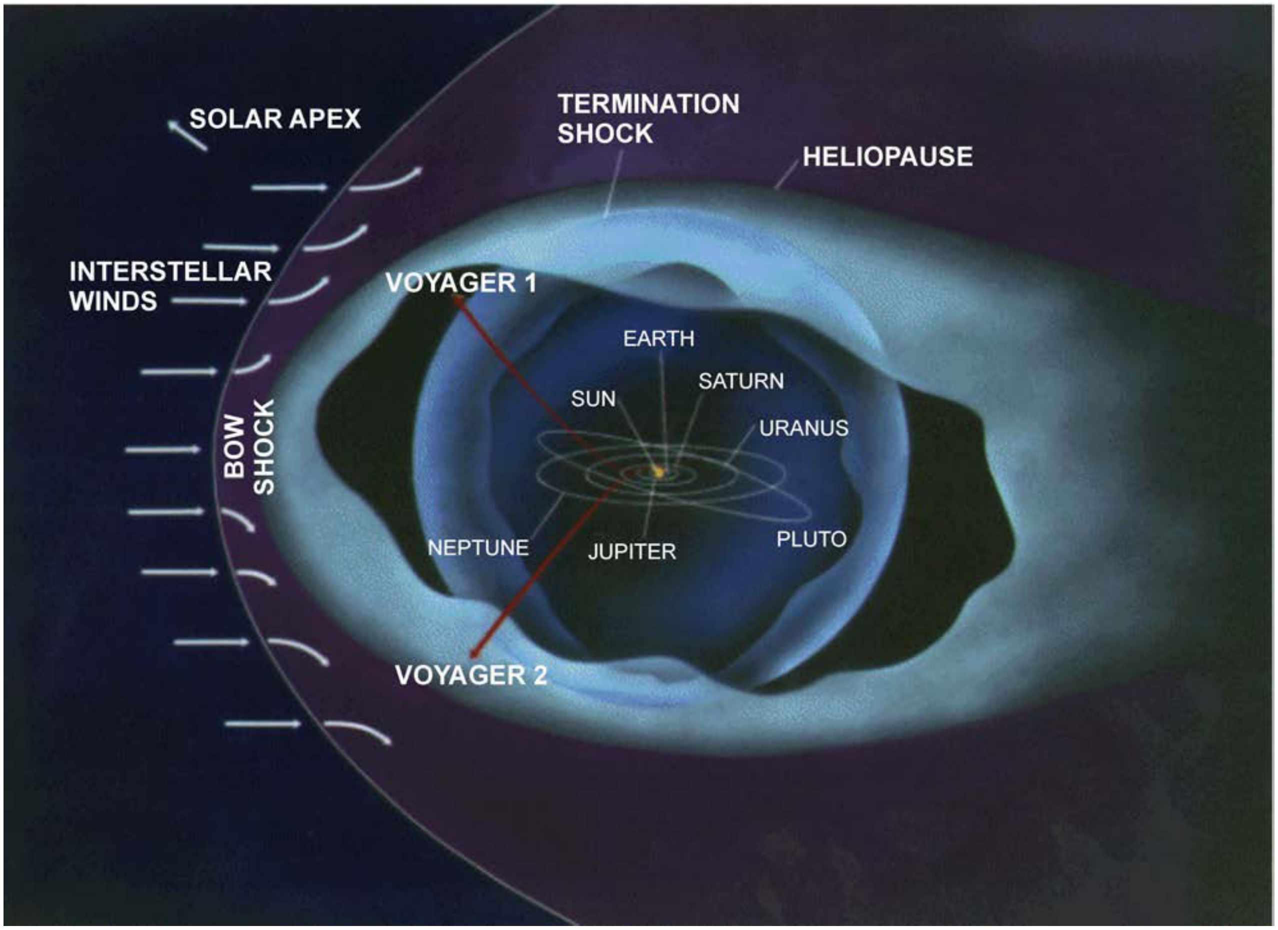
"Voyager: The Intersteller Mission", by NASA, 2004, Planetary Voyage. Retrieved April 8, 2008, from http://voyager.jpl.nasa.gov/science/heliocentric.html

Figure 15Q-1 Planetary Voyage



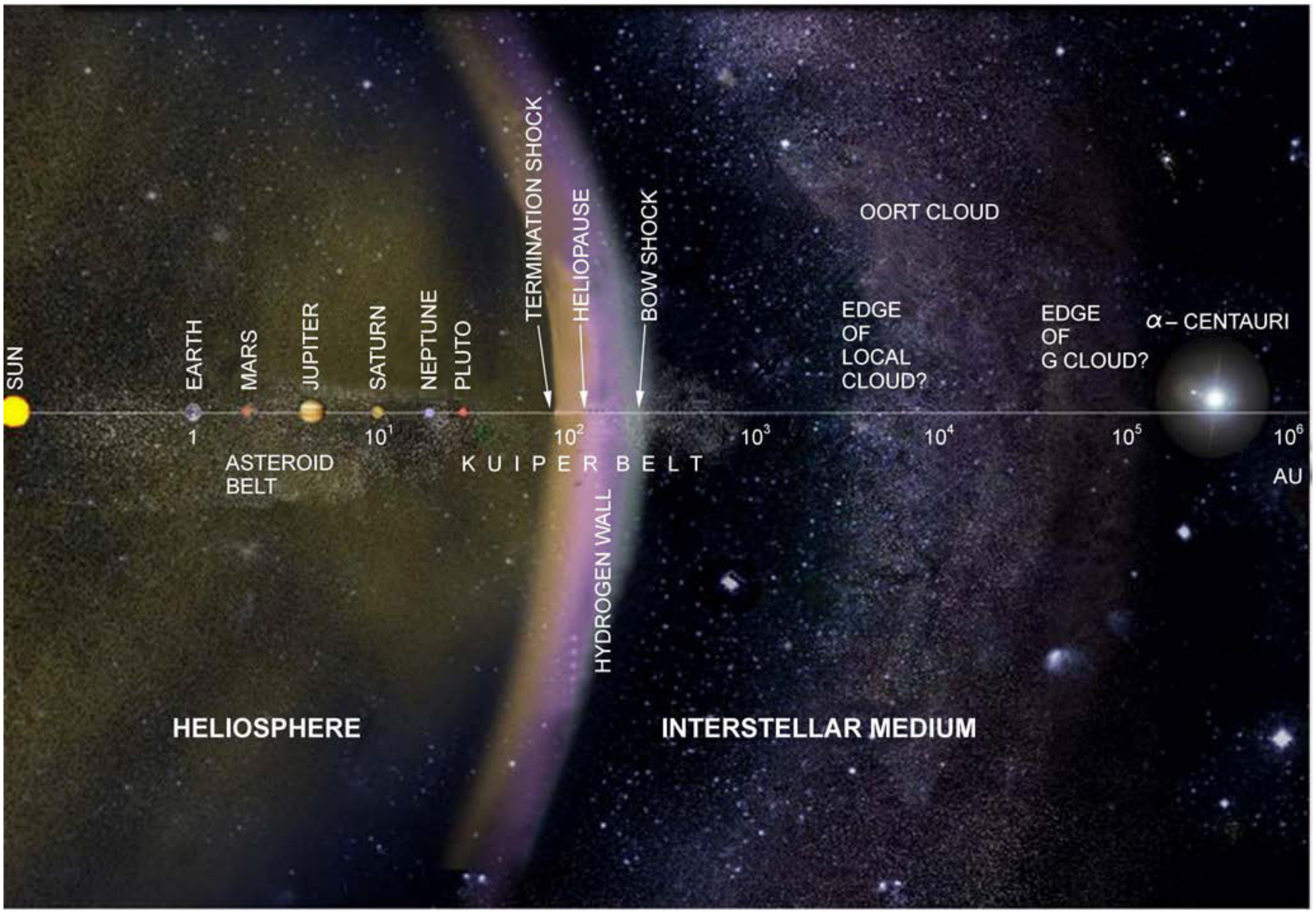
"Voyager: The Intersteller Mission", by NASA, 2004, Voyager Spacecraft. Retrieved April 8, 2008, from http://voyager.jpl.nasa.gov/spacecraft/instruments.html

Figure 15Q-2 Voyager Configuration



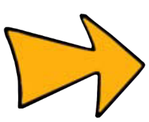
"Voyager: The Intersteller Mission", by NASA, 2007, Overview. Retrieved April 8, 2008, from http://voyager.jpl.nasa.gov/mission/mission.html

Figure 15Q-3 Voyager Interstellar Mission



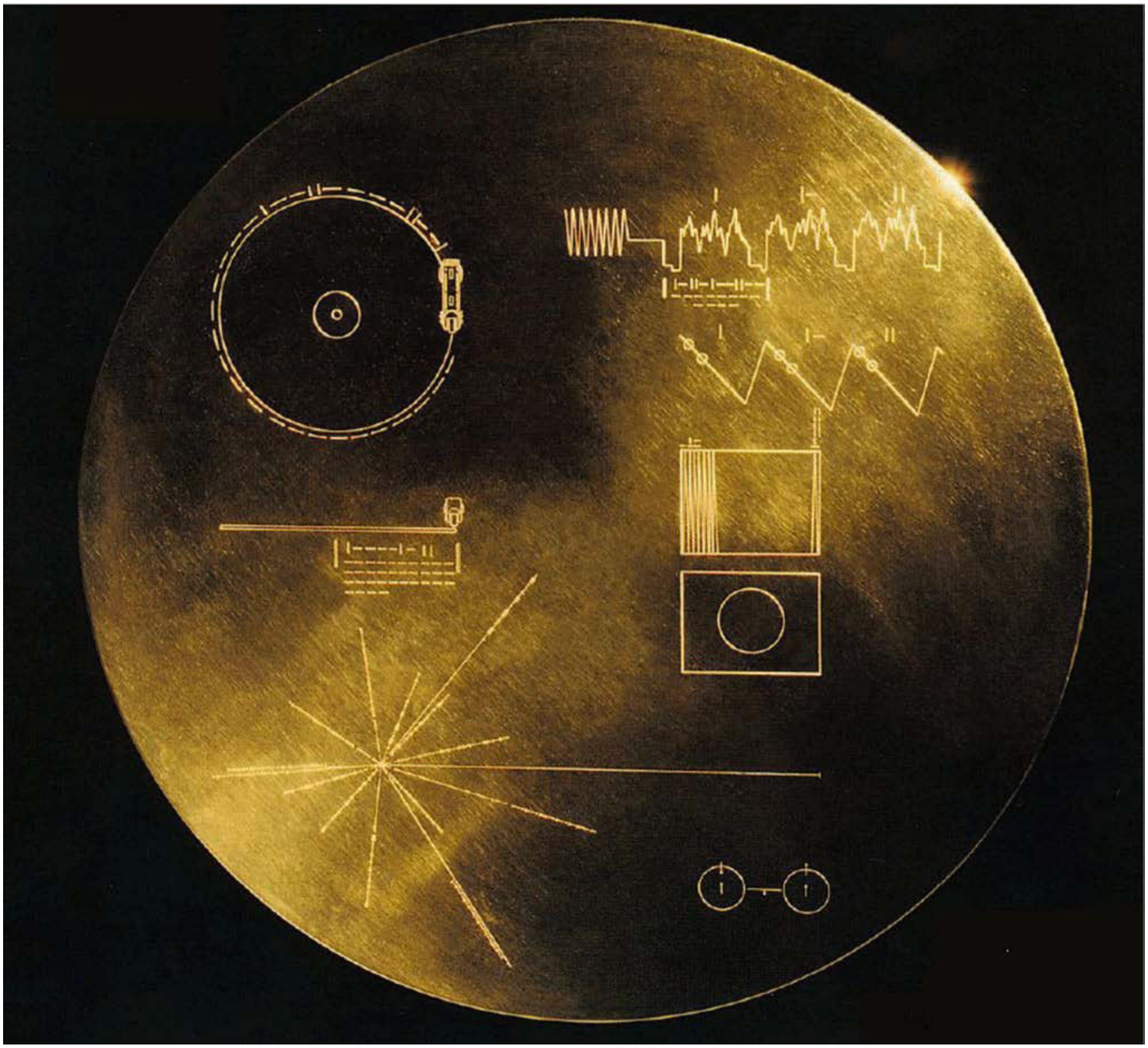
"Voyager: The Intersteller Mission", by NASA, 2004, Did You Know: Interesting Facts About the Voyager Mission. Retrieved April 8, 2008, from http://voyager.jpl.nasa.gov/mission/didyouknow.html

Figure 15Q-4 Sol's Heliopause



For current distances of the Voyagers, cadets can check mission weekly reports at NASA website http://voyager.jpl.nasa.gov/mission/weekly-reports/index.htm.

The distance from earth to the sun (approximately 149 598 000 km – this dimension is not perfectly stable) is said to be one astronomical unit (AU). Such a huge unit of measure is useful when dealing with astronomical dimensions. The vertical dimension shown in Figure 15Q-4 is therefore approximately 5 AU. The horizontal dimension, however, includes all the space between earth's sun, Sol, and Alpha Centauri – Sol's closest neighbour – 277 600 AU. To cover this vast space, the horizontal scale was altered so that it increases as the viewer moves from left to right. The scale changes are marked on the central horizontal line, as 10^1,10^2,10^3 10^4,10^5 and 10^6. This means that the distance between each pair of marks on the horizontal line is ten times larger than the distance between the preceding pairs of marks. That is, Saturn's orbit is only 10 AU from the sun, 10^3 is one thousand AU from the sun, while 10^6 is one million AU from the sun – well past Alpha Centauri. This method (logarithmic representation) is necessary for representing astronomical distances.



"Voyager: The Intersteller Mission", by NASA, 2003, The Golden Record. Retrieved April 8, 2008, from http://voyager.jpl.nasa.gov/spacecraft/goldenrec1.html

Figure 15Q-5 The Golden Record

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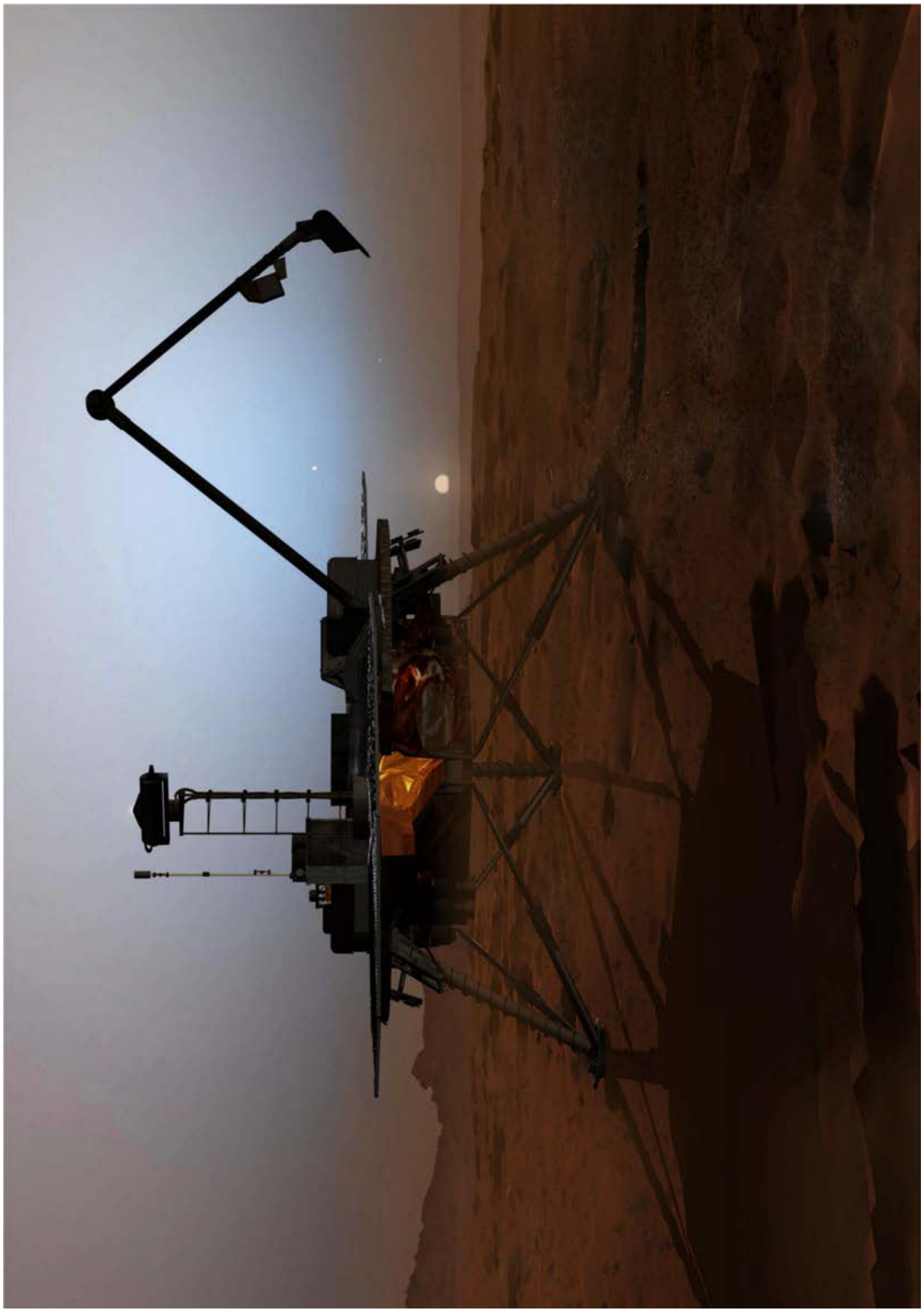
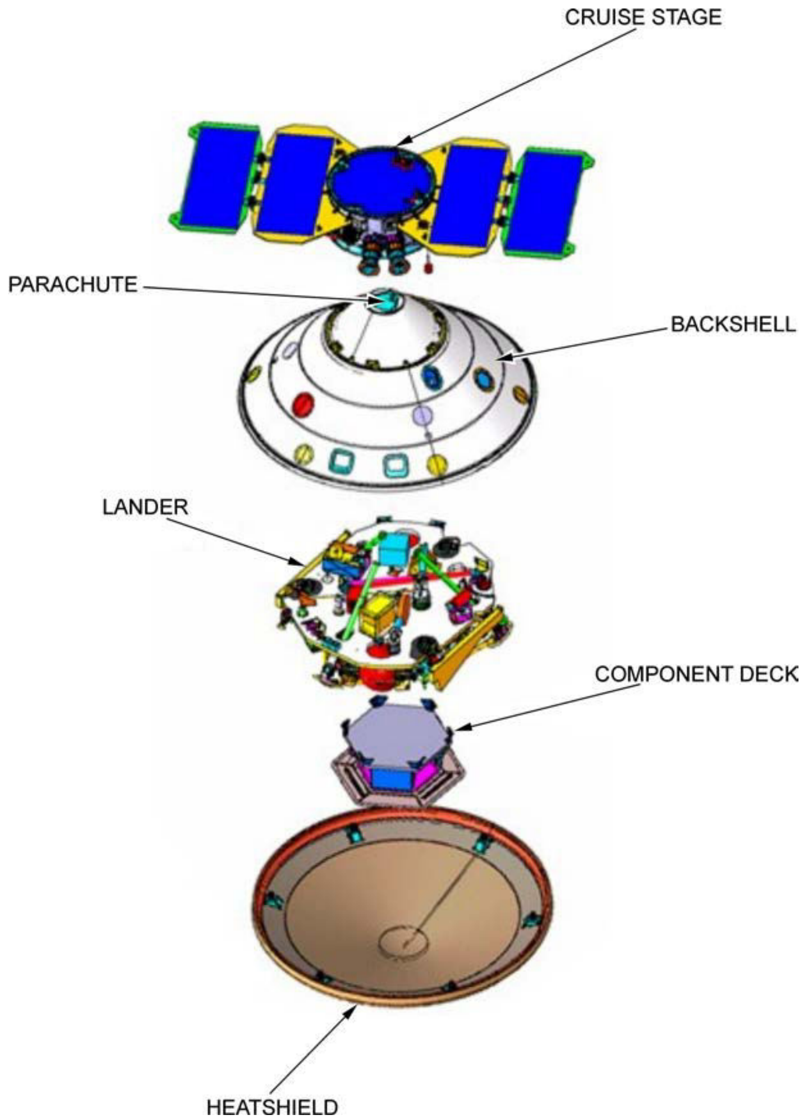
MARS MISSION



"Phoenix Mars Mission", by NASA, 2008, The Spacecraft. Retrieved April 6, 2008 from http://phoenix.lpl.arizona.edu/images.php?gID=301&cID=1

Figure 15R-1 Phoenix Mars Lander



"Phoenix Mars Mission", by NASA, 2008, The Spacecraft. Retrieved April 6, 2008, from http://phoenix.lpl.arizona.edu/images.php?gID=301&cID=1

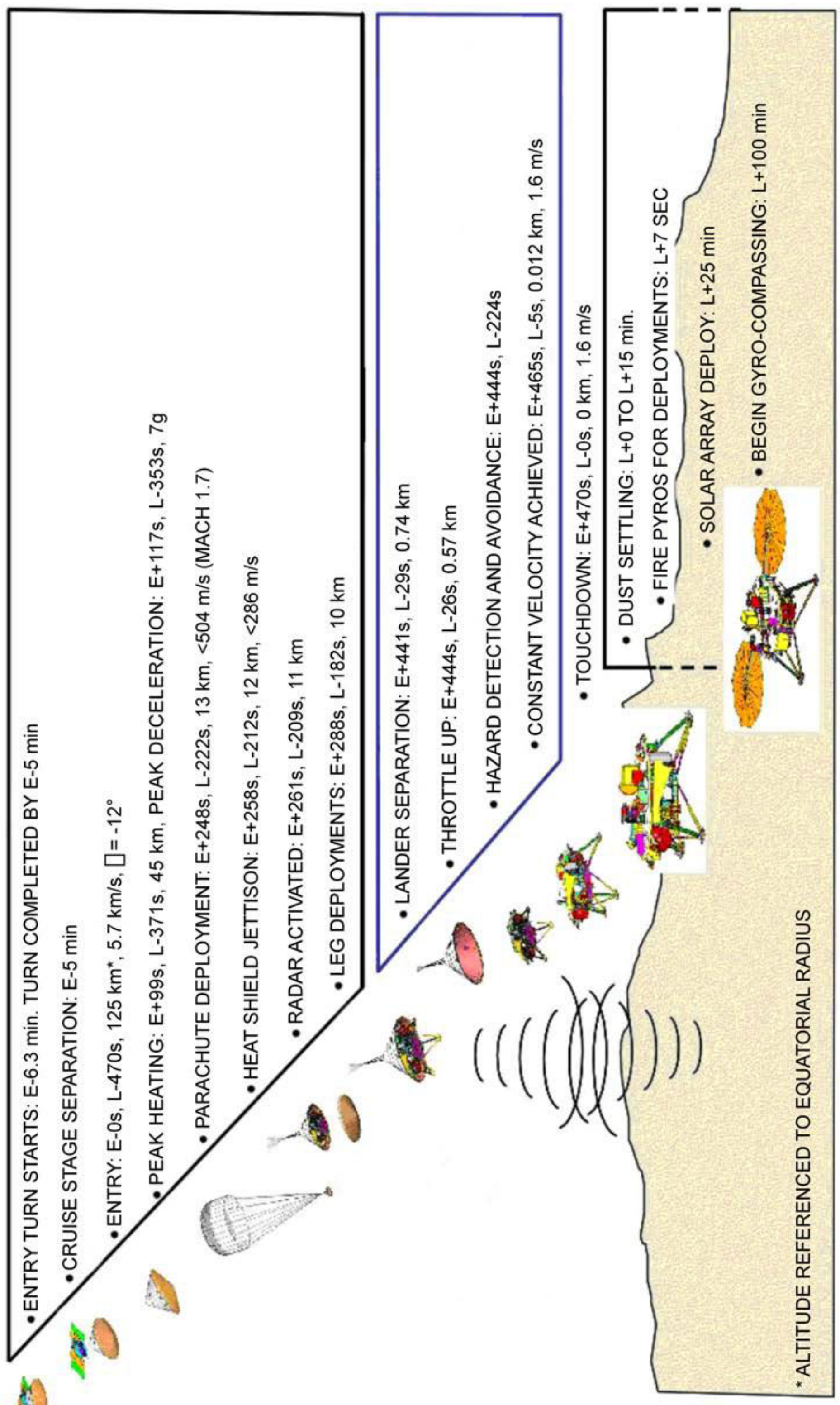
Figure 15R-2 Phoenix Revealed

"Phoenix Mars Mission", by NASA, 2008, The Spacecraft. Retrieved April 6, 2008, from http://phoenix.lpl.arizona.edu/images.php?gID=301&cID=1

Figure 15R-3 Testing the Spacecraft

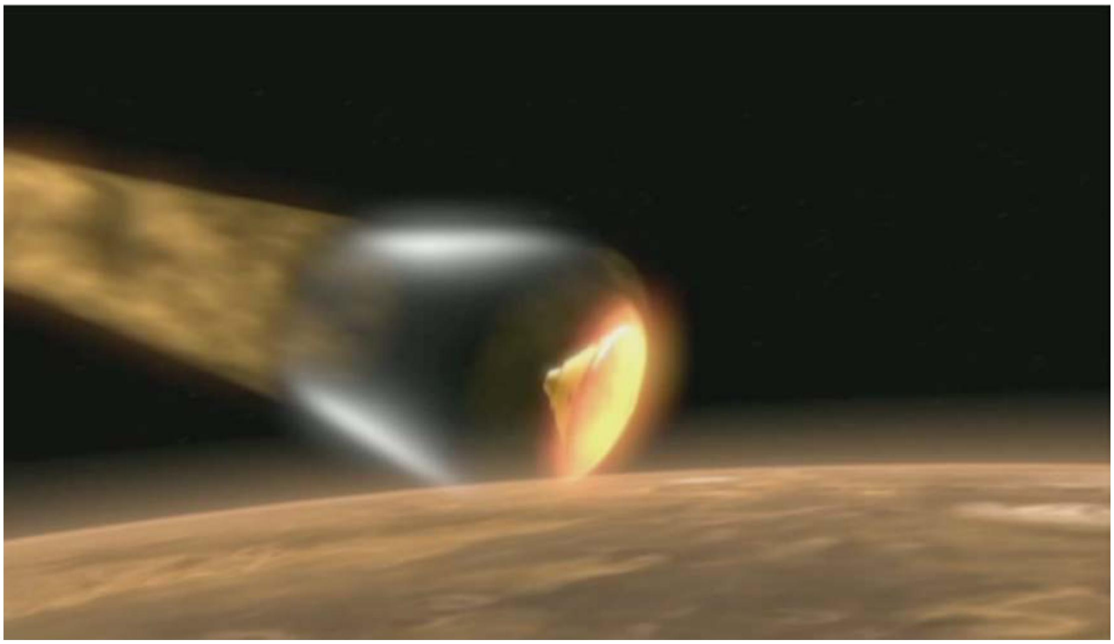
"Phoenix Mars Mission", by NASA 2008, The Spacecraft. Retrieved April 6, 2008, from http://phoenix.lpl.arizona.edu/images.php?gID=301&cID=1

Figure 15R-4 Jettisoning the Cruise Stage at Entry Minus 5 Min



"Phoenix Mars Mission", by NASA, 2008, The Spacecraft. Retrieved April 6, 2008 from http://phoenix.lpl.arizona.edu/images.php?gID=301&cID=1

Figure 15R-5 Phoenix Arriving



"Phoenix Mars Mission", by NASA, 2008, The Spacecraft. Retrieved April 6, 2008 from http://phoenix.lpl.arizona.edu/images.php?gID=301&cID=1

Figure 15R-6 Entering the Martian Atmosphere at Entry Plus 99 Seconds

"Phoenix Mars Mission", by NASA, 2008, The Spacecraft. Retrieved April 6, 2008 from http://phoenix.lpl.arizona.edu/images.php?gID=301&cID=1

Figure 15R-7 Powered Landing on Mars at Entry Plus 470 Seconds

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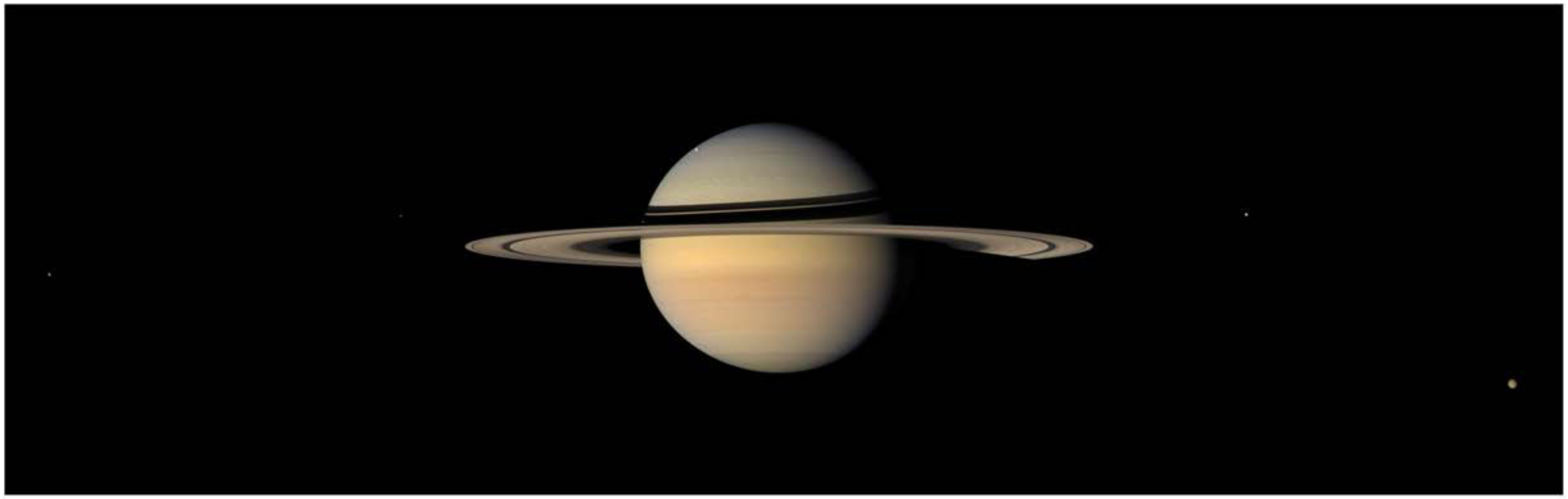
MOONS VIDEO WORKSHEET

Notes:

1. The information is encountered in the same order as the questions.
2. Read the questions carefully before beginning the MOONS video.

QUESTIONS

1. How long ago do scientists think that Earth's moon was formed? ________________________________
2. How many years did NASA's Galileo probe spend exploring Jupiter's moons? ________________________________
3. What lies under Europa's frozen crust? ________________________________
4. What year did the European Space agency launch Cassini-Huygens? ________________________________
5. How long did it take the Cassini-Huygens probe to travel to Saturn? ________________________________
6. What kind of scientist is the narrator, Athena Coustenis? ________________________________
7. What is Saturn's most distant moon? ________________________________
8. What year did Jean-Dominique Cassini discover Saturn's moon Iapetus? ________________________________
9. Half of Iapetus is dark as coal; what is the other half? ________________________________
10. What runs around the equator of Iapetus? ________________________________
11. What is the largest moon of Saturn? ________________________________
12. What year did the Cassini spacecraft release the Huygens probe to visit Titan? ________________________________
13. How long did Huygens operate on Titan's surface? ________________________________



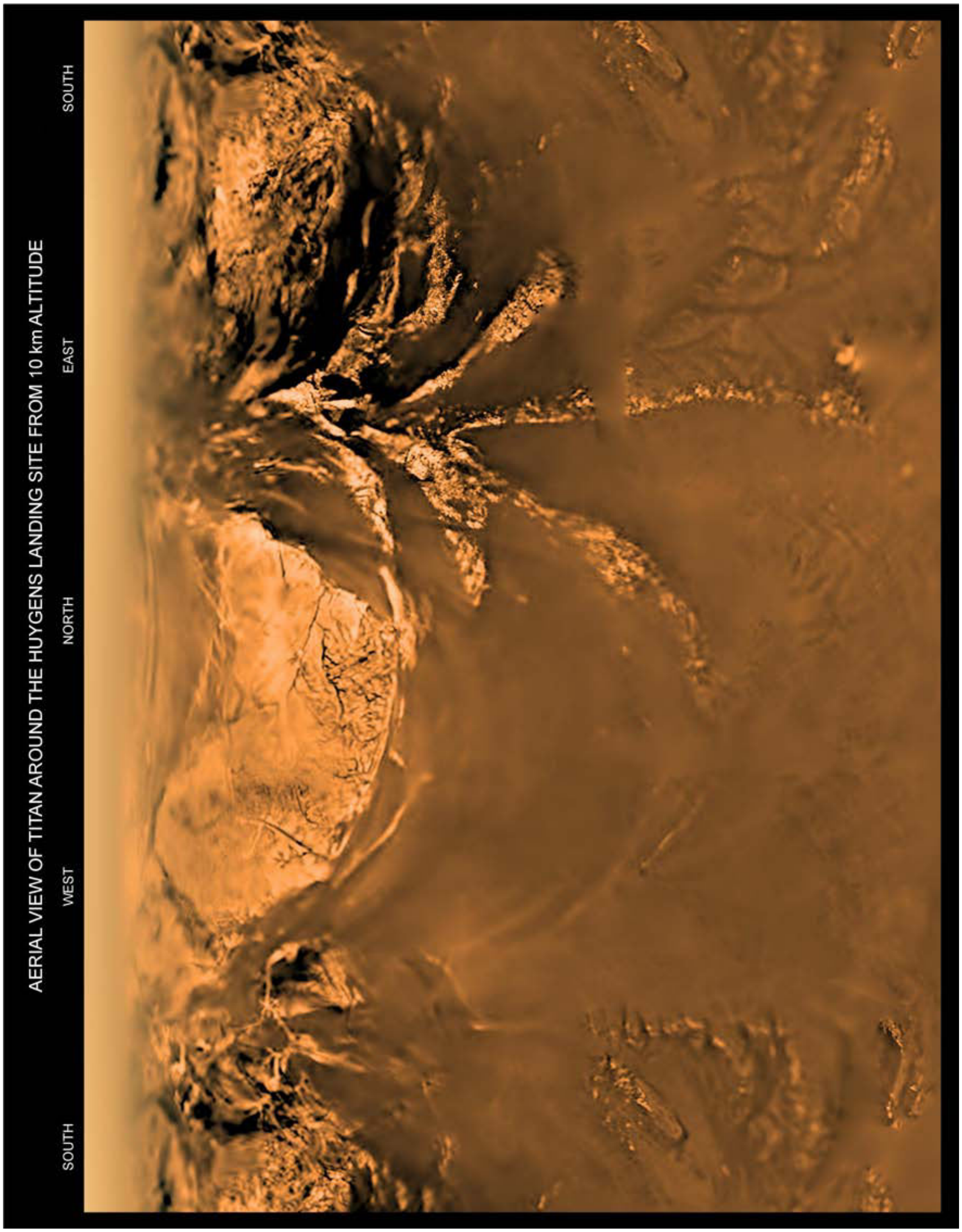
While on final approach for its September 2007 close encounter with Saturn's moon, Iapetus, Cassini spun around to take in a sweeping view of the Saturn System. Iapetus (1 468 km, or 912 miles across) is the only major moon of Saturn with a significant inclination to its orbit. From the other major satellites, the rings would appear nearly edge-on, but from Iapetus, the rings usually appear at a tilt, as seen here.

Moons visible in this image: **Dione** (1 126 km diameter) at center left, **Enceladus** (505 km diameter) near the left side ansa (or ring edge), **Mimas** (397 km diameter) a speck against the ring shadows on Saturn's western limb, **Rhea** (1 528 km diameter) against the bluish backdrop of the northern hemisphere, **Tethys** (1 071 km diameter) near the right ansa, and **Titan** (5 150 km diameter) near lower right.

The images were obtained on September 10, 2007, at a distance of approximately 3.3 million km from Saturn at a sun-Saturn-spacecraft, or phase, angle of 33 degrees. Image scale is about 195 km per pixel on the planet.

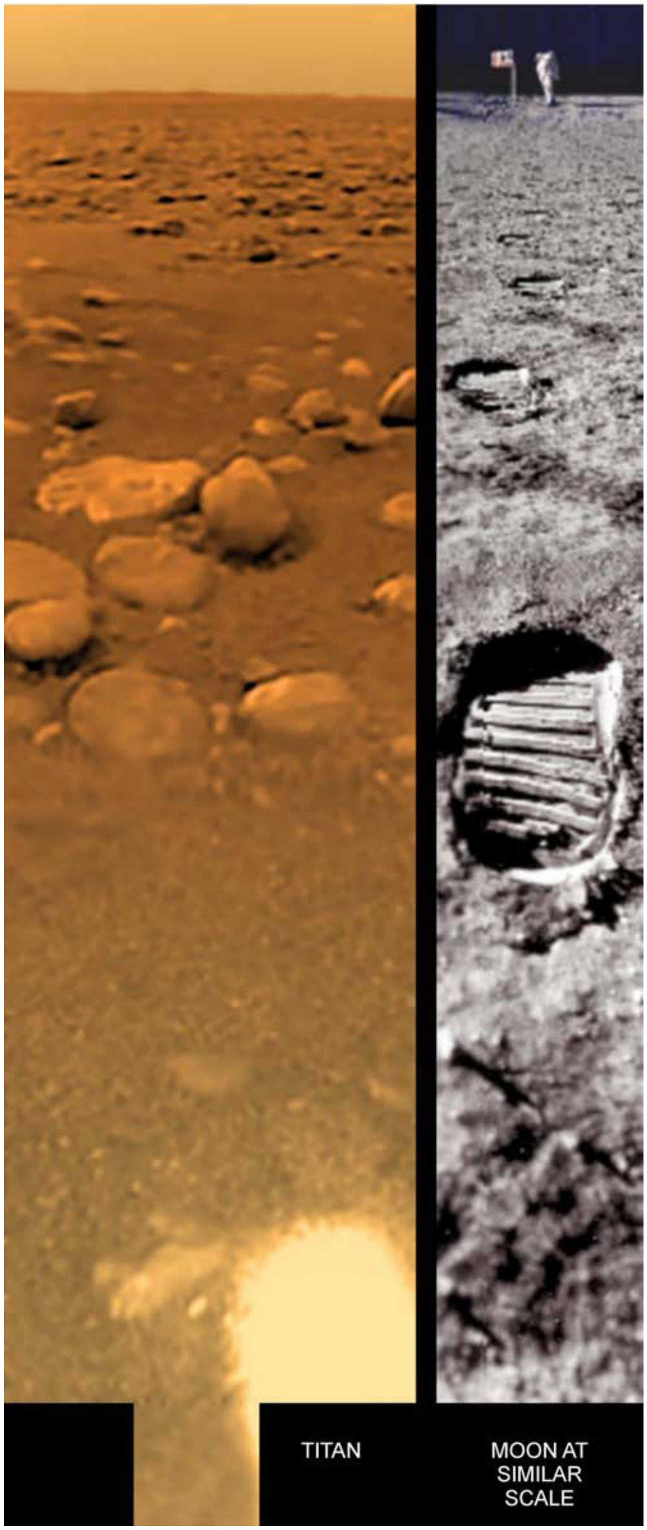
"JPL PHOTOJOURNAL", by NASA, 2007, PIA08387: The View from Iapetus. Retrieved April 6, 2008, from http://photojournal.jpl.nasa.gov/catalog/PIA08387

Figure 15S-1 Saturn, Enceladus and Titan



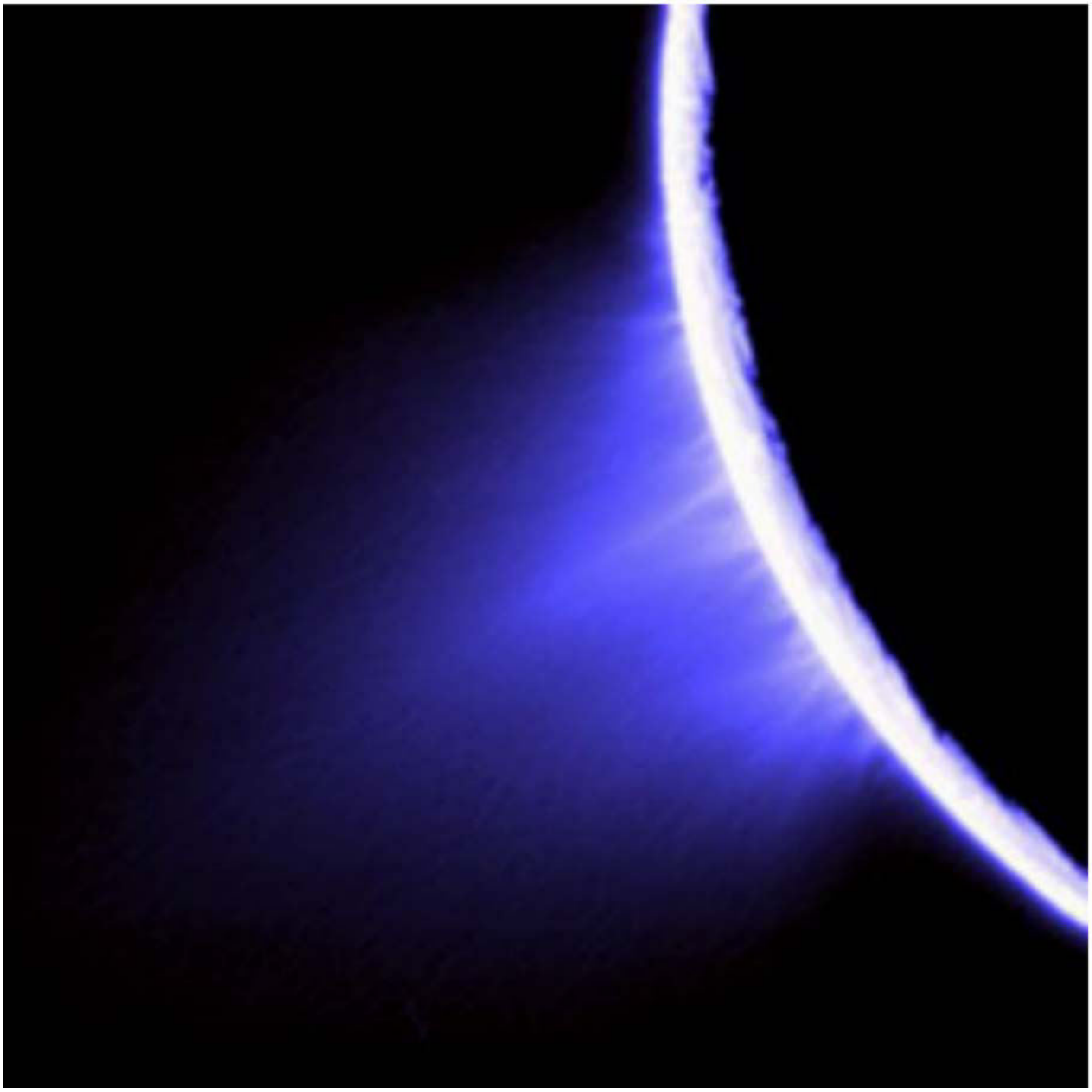
ESA Multimedia Gallery, 2008, Mercator Projection of Huygens's View. Retrieved April 6, 2008, from http://www.esa.int/esa-mmg/mmg.pl?b=b&keyword=titan%20huygens&single=y&start=25&size=b

Figure 15S-2 Huygen's Descent



"ESA Multimedia Gallery", 2008, Titan's Surface. Retrieved April 6, 2008, from http://www.esa.int/esa-mmg/mmg.pl?b=b&keyword=titan%20huygens&start=3

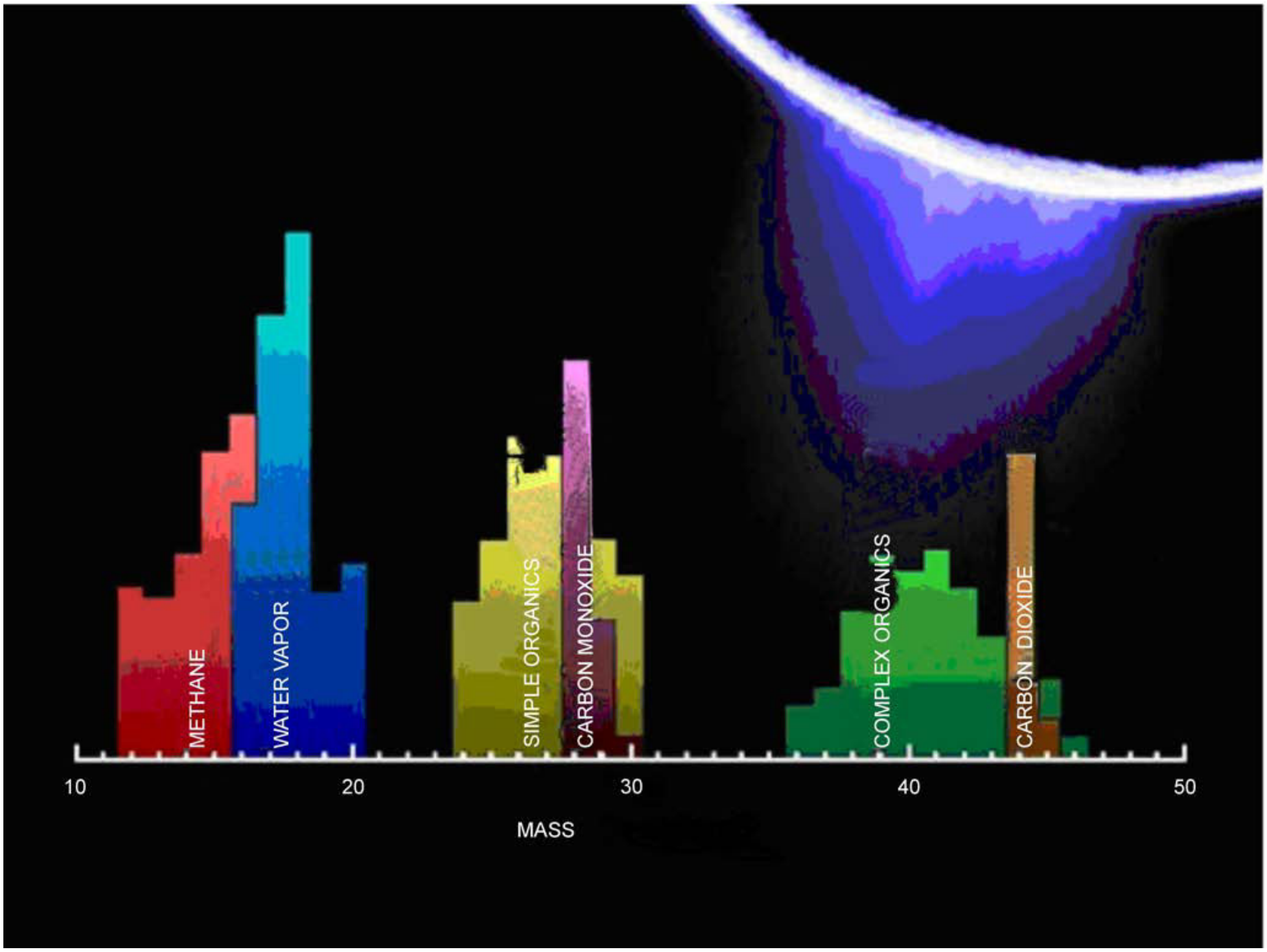
Figure 15S-3 Huygen's Resting Place



"JPL Cassini-Huygens Mission to Saturn & Titan", 2008, Jet Blue. Retrieved April 6, 2008, from http://saturn.jpl.nasa.gov/multimedia/images/image-details.cfm?imageID=2779

Figure 15S-4 The Fountains of Enceladus

Enceladus [en-SELL-ah-dus] is one of the innermost moons of Saturn. Enceladus reflects almost 100 percent of the sunlight that strikes it. Parts of Enceladus show craters 35 km in diameter. Other areas show regions with no craters indicating major resurfacing events in the geologically recent past. There are fissures, plains, corrugated terrain and other crustal deformations. All of this indicates that the interior of the moon may be liquid today, even though it should have frozen eons ago. It is postulated that Enceladus is heated by a tidal mechanism. It is disturbed in its orbit by Saturn's gravitational field and by the large neighbouring satellites Tethys and Dione. Enceladus reflects so much sunlight that its surface temperature is only -201 degrees C (-330 degrees F).



"Cassini: Unlocking Saturn's Secrets", NASA, 2008, Enceladus Plume Neutral Mass Spectrum. Retrieved April 6, 2008, from http://www.nasa.gov/mission_pages/cassini/multimedia/pia10356.html

Figure 15S-5 Composition of Enceladus' Water Plumes

ANSWERS TO *MOONS* VIDEO WORKSHEET

1. How long ago do scientists think that Earth's moon was formed? **4.5 billion years**
2. How many years did NASA's Galileo probe spend exploring Jupiter's moons? **8 years**
3. What lies under Europa's frozen crust? **A liquid ocean**
4. What year did the European Space agency launch Cassini-Huygens? **1997**
5. How long did it take the Cassini-Huygens probe to travel to Saturn? **7 years**
6. What kind of scientist is the narrator, Athena Coustenis? **Astrophysicist**
7. What is Saturn's most distant moon? **Phoebe**
8. What year did Jean-Dominique Cassini discover Saturn's moon Iapetus? **1671**
9. Half of Iapetus is dark as coal; what is the other half? **Bright as snow**
10. What runs around the equator of Iapetus? **An icy ridge**
11. What is the largest moon of Saturn? **Titan**
12. What year did the Cassini spacecraft release the Huygens probe to visit Titan? **2005**
13. How long did Huygens operate on Titan's surface? **Barely a few minutes**

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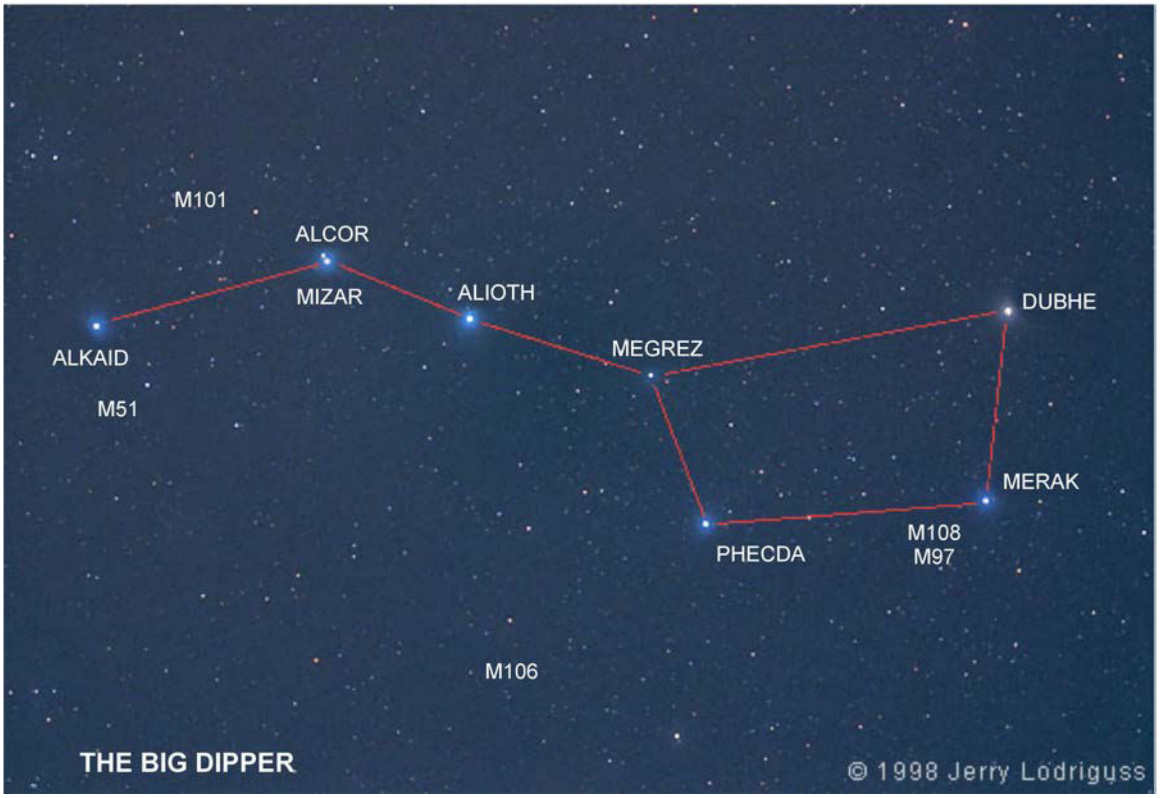
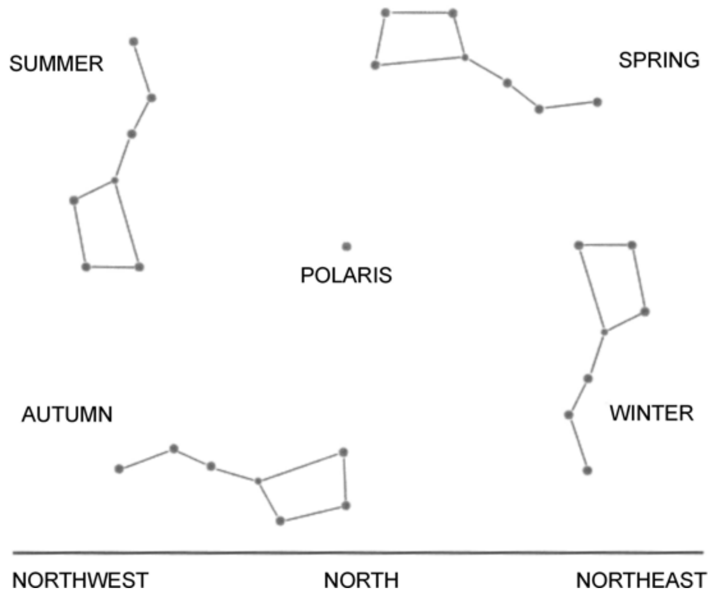
CONSTELLATIONS



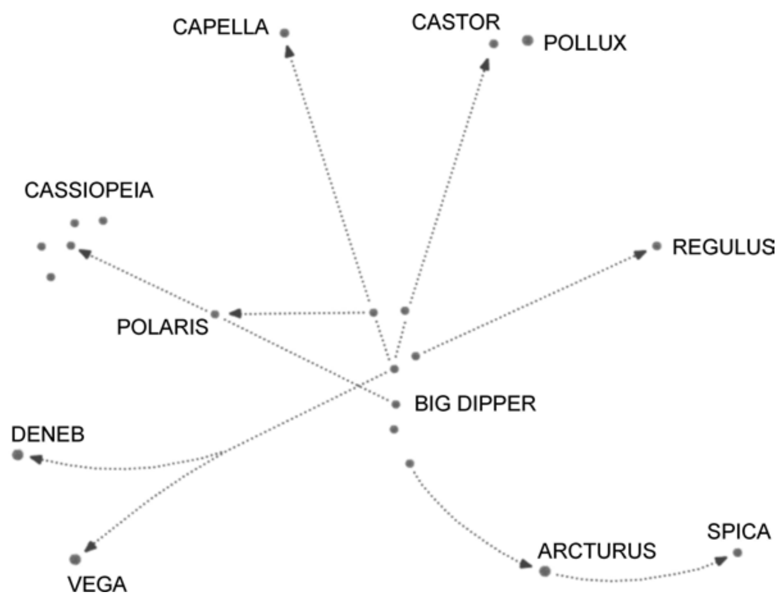
Catching the Light: Astrophotography by Jerry Lodriguss, 1998. Retrieved March 1, 2008, from http://www.astropix.com/HTML/C_SPRING/BIGDIP.HTM

Figure 15U-1 The Big Dipper in Constellation Ursa Major



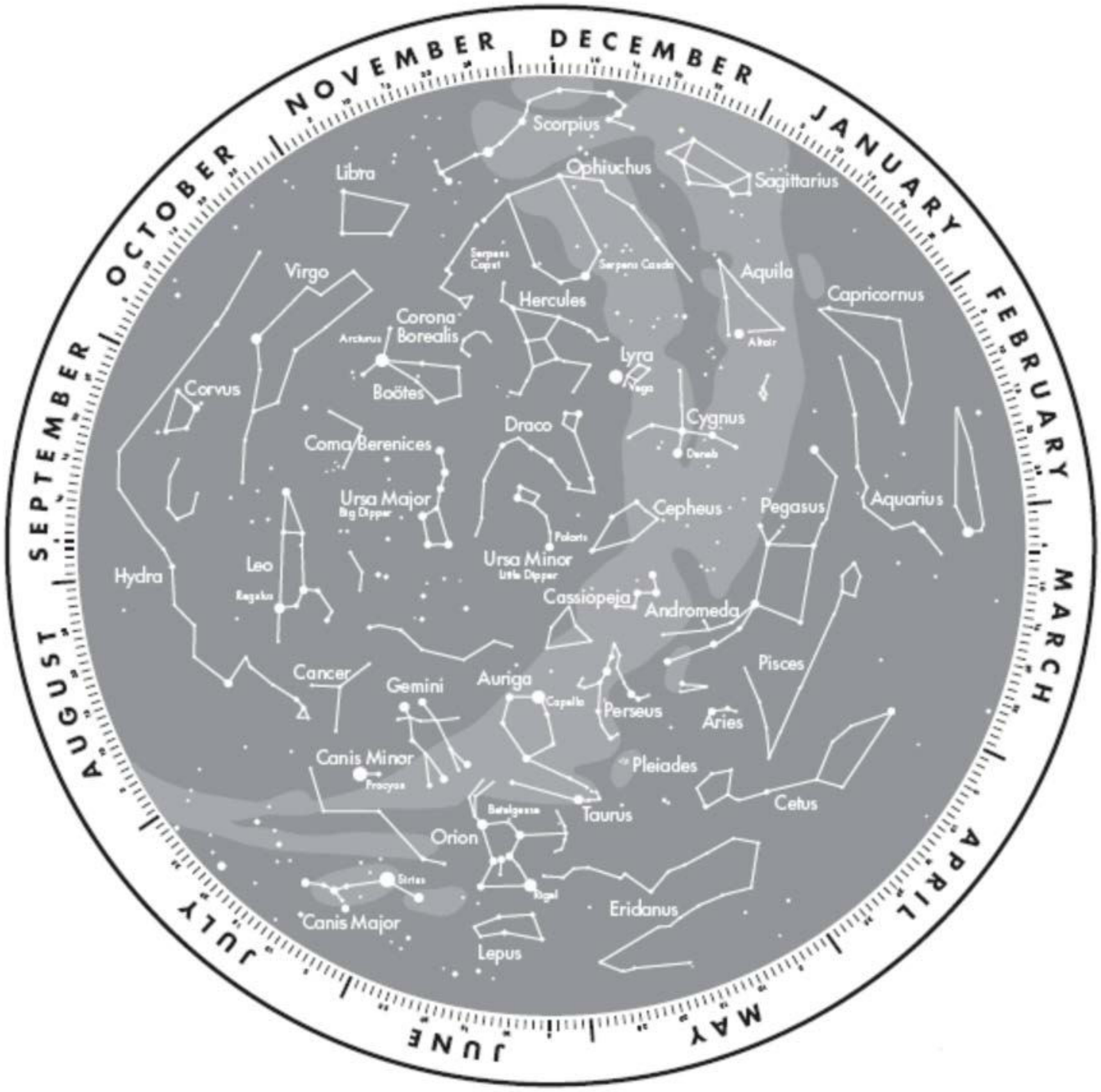
T. Dickinson, NightWatch: A Practical Guide to Viewing the Universe, Firefly Books Ltd. (p. 31)

Figure 15U-2 Orientations of the Big Dipper



T. Dickinson, NightWatch: A Practical Guide to Viewing the Universe, Firefly Books Ltd. (p. 31)

Figure 15U-3 Big Dipper as the Key to the Night Sky



Constellations, by National Research Council of Canada. Retrieved March 1, 2008, from http://www.nrc-cnrc.gc.ca/docs/education/planisphere_e.pdf

Figure 15U-4 Constellations

Constellations are patterns of stars partitioned and named long ago by our ancestors. Of the 88 constellations recognized by the International Astronomical Union approximately one quarter of these are in the southern sky and not visible from mid-northern latitudes. About half of the remaining constellations are faint and hard to distinguish. Many of the visible and well-known constellations are shown in this handout. All constellations, including Ursa Major (the Big Dipper), circle the sky every 24 hours, with Polaris – the North Star – at the centre of the circle.

SIGHTING OPPORTUNITIES

On February 8, 2008, the space shuttle Atlantis, flying mission STS-122, was delivering the European Space Agency's (ESA) Columbus Laboratory module to the International Space Station (ISS). This momentous event brought the ESA's Columbus Control Center in Oberpfaffenhofen, Germany online for the first time. Coincidentally, the Progress P28 supply ship had just arrived from the Baikonur Cosmodrome in Kazakhstan the previous day to replace Progress P27 which was then de-orbited to burn up in the earth's atmosphere. The sighting opportunities listed below show not only the ISS and Atlantis, but also a last glimpse of Progress P27 before final re-entry.

ONLY DAYS WITH SIGHTING OPPORTUNITIES ARE LISTED
THE FOLLOWING SHUTTLE SIGHTINGS ARE POSSIBLE FROM FRI FEB 08 TO SUN FEB 24

SATELLITE	LOCAL DATE/TIME	DURATION (MIN)	MAX ELEV (DEG)	APPROACH (DEG-DIR)	DEPARTURE (DEG-DIR)
SHUTTLE	Fri Feb 08/07:17 PM	< 1	24	18 above WNW	24 above NW

ONLY DAYS WITH SIGHTING OPPORTUNITIES ARE LISTED
THE FOLLOWING PROGRESS SIGHTINGS ARE POSSIBLE FROM FRI FEB 08 TO SAT FEB 16

SATELLITE	LOCAL DATE/TIME	DURATION (MIN)	MAX ELEV (DEG)	APPROACH (DEG-DIR)	DEPARTURE (DEG-DIR)
PROGRESS	Fri Feb 08/07:14 PM	1	48	20 above WNW	48 above NNW

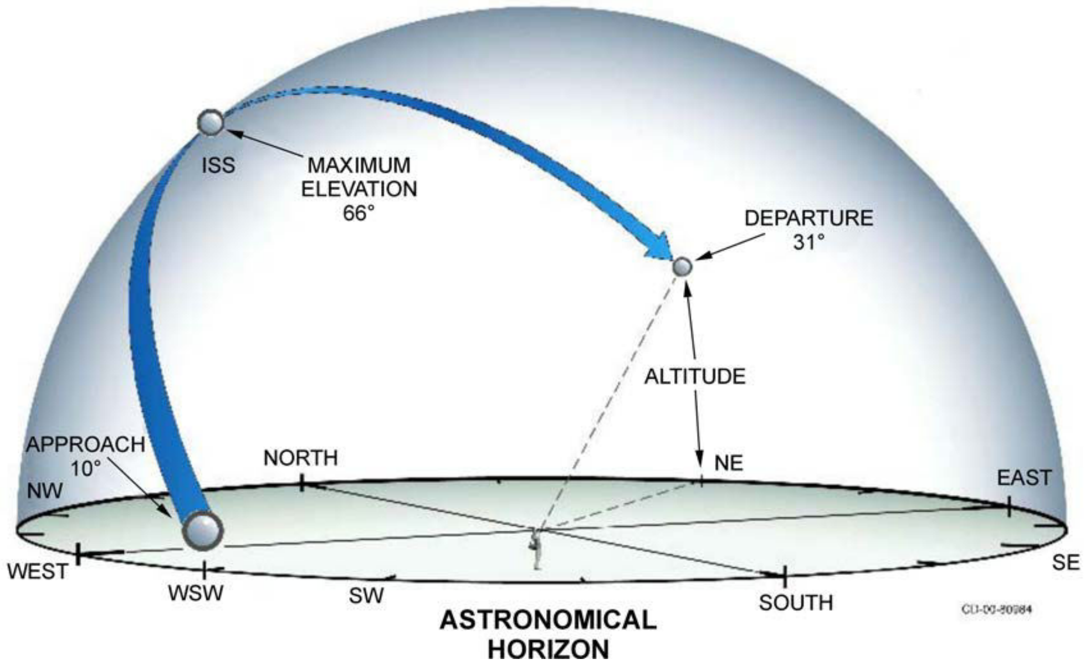
THE FOLLOWING ISS SIGHTINGS ARE POSSIBLE FROM FRI FEB 08 TO WED FEB 20

SATELLITE	LOCAL DATE/TIME	DURATION (MIN)	MAX ELEV (DEG)	APPROACH (DEG-DIR)	DEPARTURE (DEG-DIR)
ISS	Fri Feb 08/07:04 PM	2	51	20 above WNW	51 above N

HUMANSPACEFLIGHT: Sighting Opportunities by NASA, 2003. Retrieved February 8, 2008, from http://spaceflight.nasa.gov/realdata/sightings/

Figure 15V-1 Sighting Opportunities

SATELLITE	LOCAL DATE/TIME	DURATION (MIN)	MAX ELEV (DEG)	APPROACH (DEG-DIR)	DEPARTURE (DEG-DIR)
ISS	Tue Nov 14/06:22 AM	4	66	10 above WSW	31 above NE



HUMANSPACEFLIGHT: Sighting Opportunities by NASA, 2003. Retrieved March 1, 2008, from http://spaceflight.nasa.gov/realdata/sightings/GIF/large_sighting.jpg

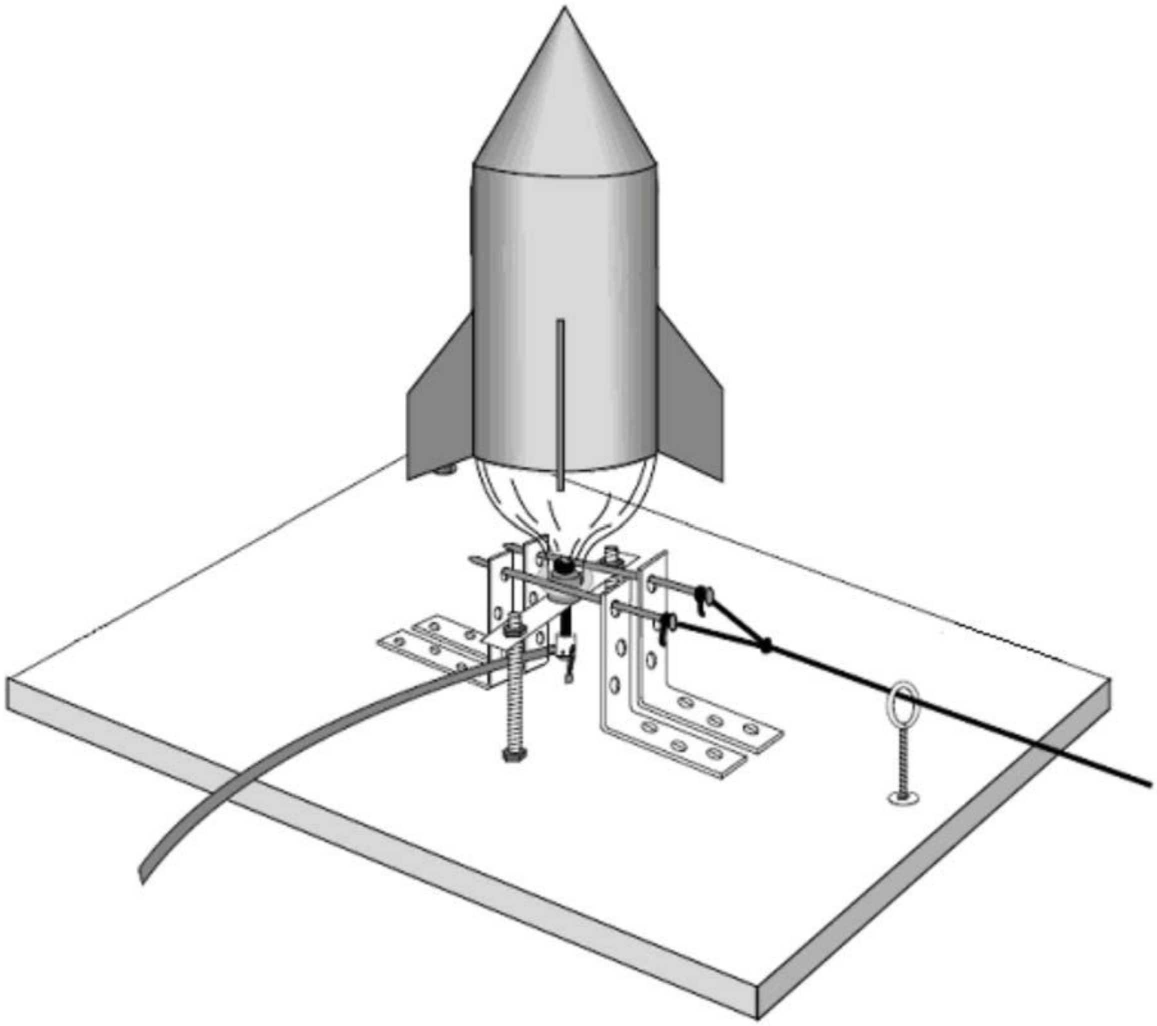
Figure 15V-2 Morning ISS Sighting

Viewing Tips

For best results, observers should look in the direction and at the elevation shown in the second column at the time listed. Telescopes are not practical because of the speed of the orbiting vehicles. However, a good pair of field binoculars may reveal some detail of the structural shape of the spacecraft. On a regular basis, the space shuttle must get rid of excess supply and waste water by dumping them overboard through water spray nozzles. Viewing the shuttle at these times through binoculars or a telescope can reveal an even more spectacular view of the spacecraft and the ice crystals that form as the water is sprayed overboard. Although you can sometimes use a flight timeline to find out when scheduled dumps occur, NASA TV is more accurate. Check the sightings list to see if a sighting opportunity and water dump overlap.

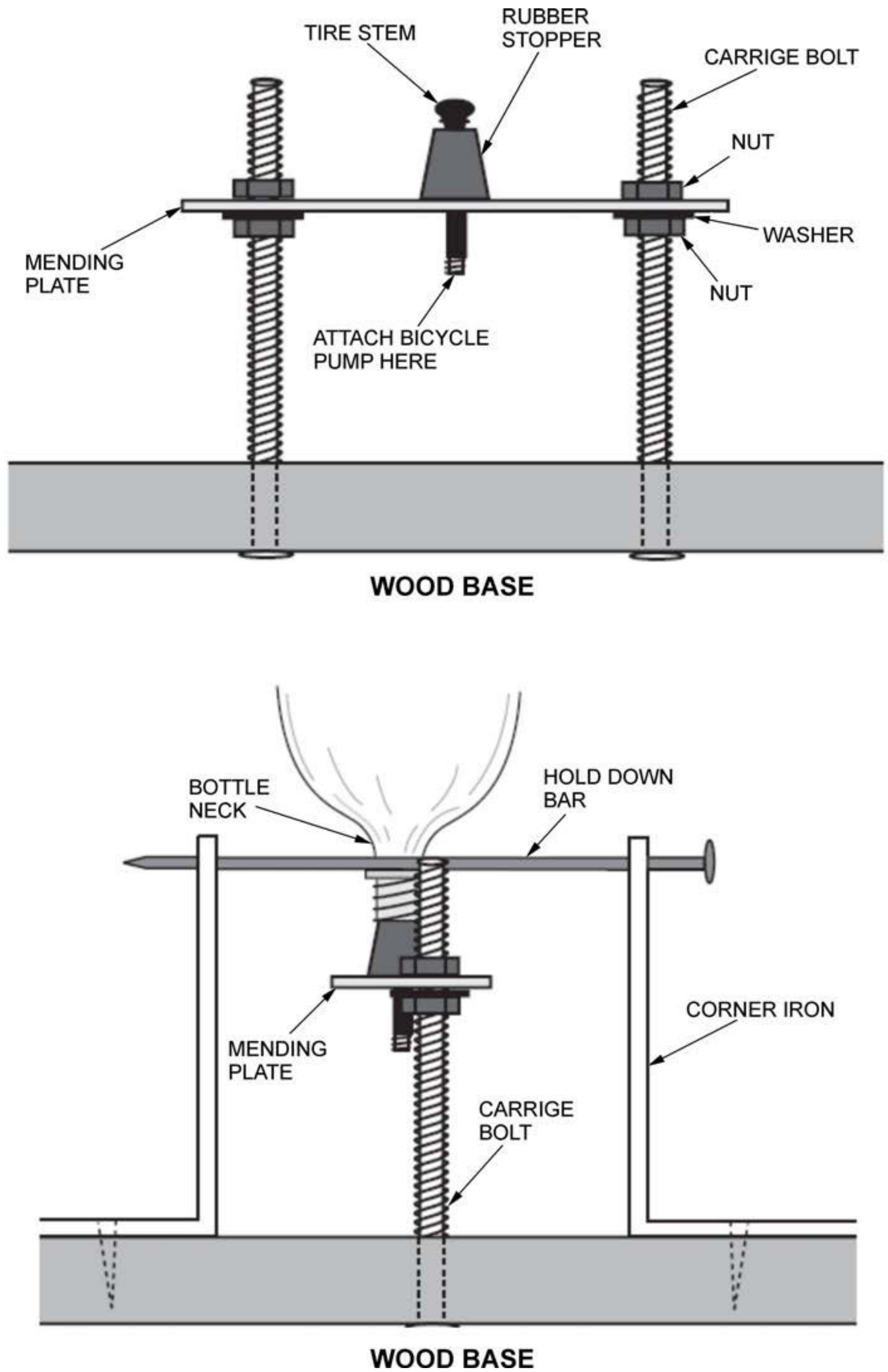
Shuttle/station docking missions provide an exciting opportunity to see a double pass. On the day or two days before docking and after undocking, the shuttle and station will appear to be chasing each other across the night sky. They will follow the same flight path varying by only a few minutes. If the distance is close enough, they will actually appear in the sky at the same time.

LAUNCHING PLATFORMS



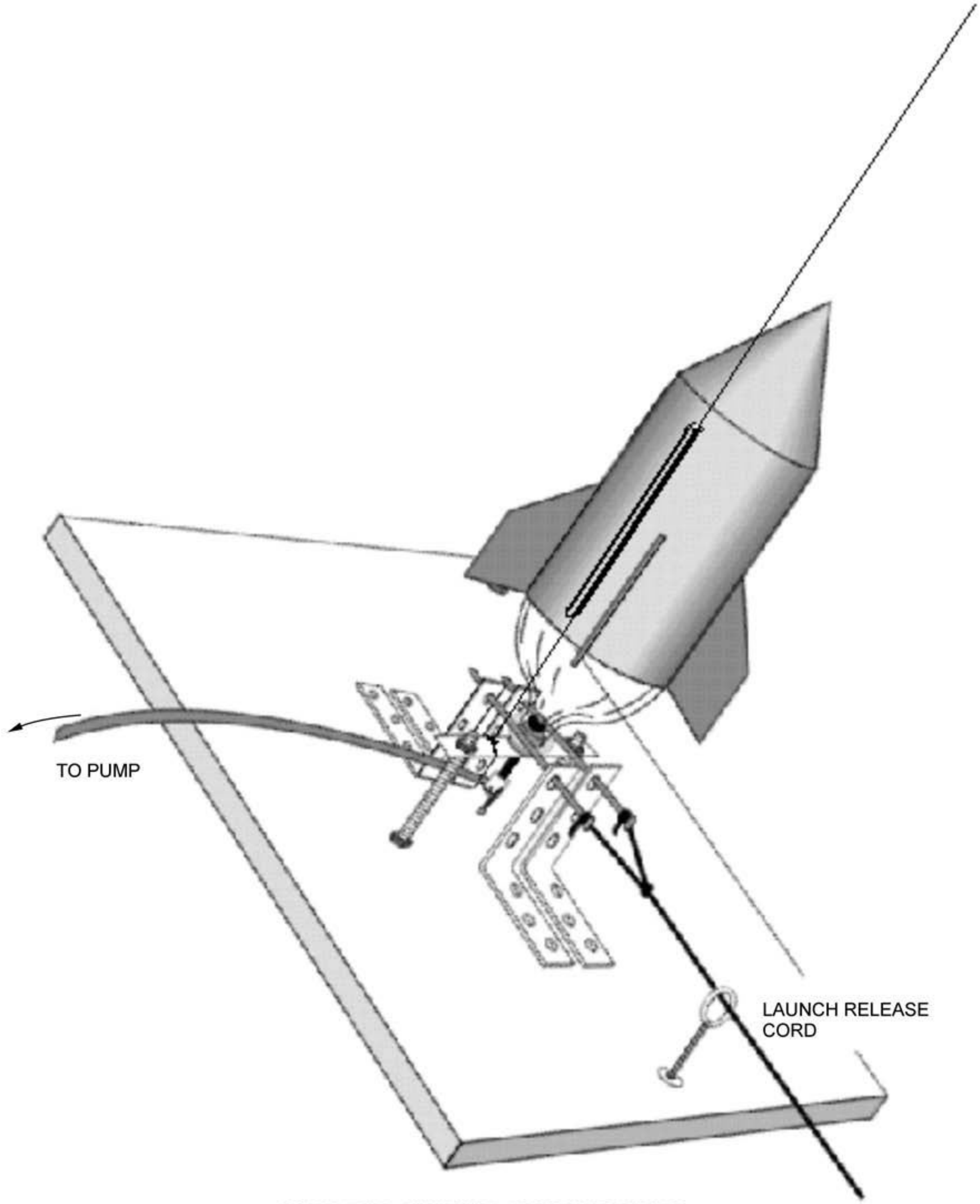
"Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology", by NASA, 2003, Bottle Rocket Launcher. Retrieved April 12, 2008, from http://www.nasa.gov/pdf/153405main_Rockets.Guide.Bottle.Rocket.Launcher.pdf

Figure 15W-1 Parts of the Launch Pad



"Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology", by NASA, 2003, Bottle Rocket Launcher. Retrieved April 12, 2008, from http://www.nasa.gov/pdf/153405main_Rockets.Guide.Bottle.Rocket.Launcher.pdf

Figure 15W-2 Details of the Launch Pad



"Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology", by NASA, 2003, Bottle Rocket Launcher. Retrieved April 12, 2008, from http://www.nasa.gov/pdf/153405main_Rockets.Guide.Bottle.Rocket.Launcher.pdf

Figure 15W-3 Launch Time

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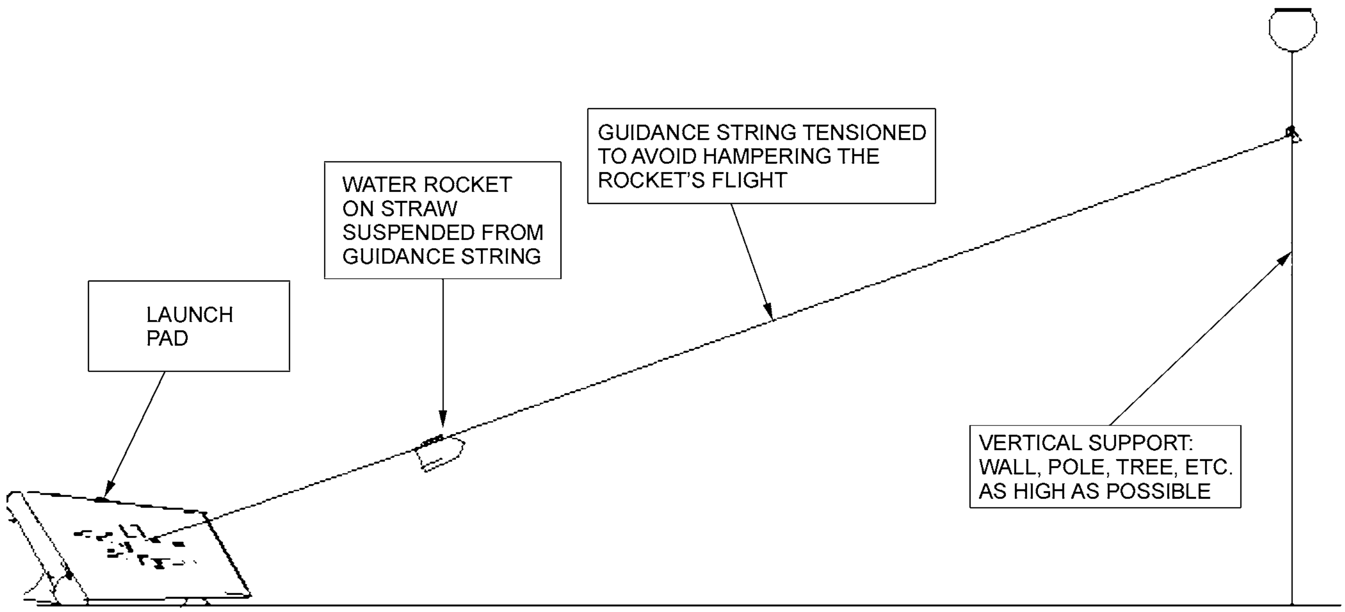
GUIDANCE SYSTEM



Director Cadets 3, 2008, Ottawa, ON: Department of National Defence

Figure 15X-1 String Guidance System

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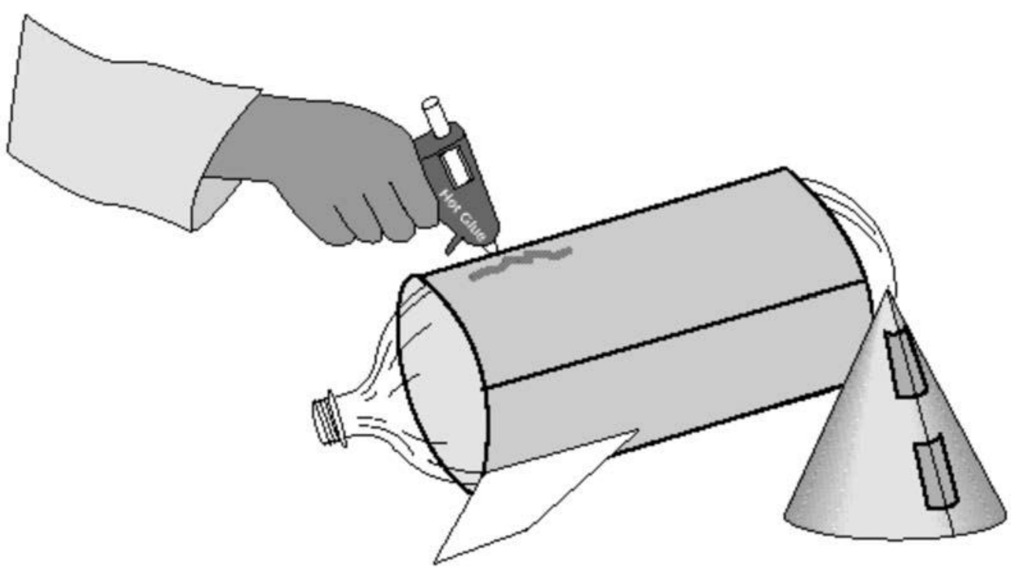
BUILDING A WATER ROCKET

Materials Required:

- One-litre soft-drink bottles with caps,
- Construction paper,
- Tape,
- Glue,
- Drill and bits, and
- Putty or modelling clay.

Hints For Construction:

- Do not allow glue to touch the plastic bottle as this may weaken the plastic and cause failure.
- Wrap and tape a tube of poster-board around the bottle.
- Cut out several fins of any shape and glue them to the tube.
- Form a nose cone and hold it together with tape or glue.
- Press a wad of modeling clay into the top of the nose cone for stability, if required.
- Tape the nose cone to upper end of bottle.
- Decorate your rocket.



"Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology", by NASA, 2003, Bottle Rocket Launcher. Retrieved April 12, 2008, from http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Bottle_Rocket_Launcher.html

Figure 15Y-1 Building a Water Rocket

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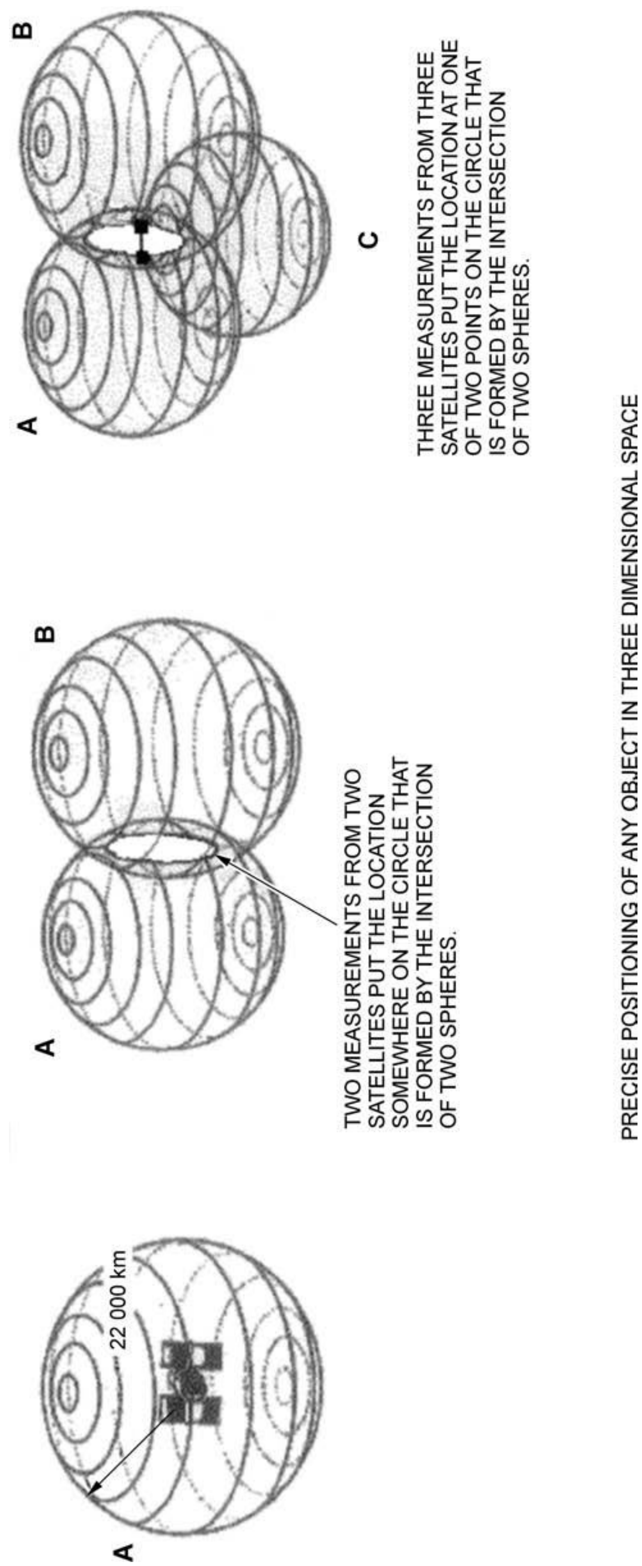
TRILATERATION



Canadian Forces, Maps, Field Sketching, Compasses and the Global Positioning System, Department of National Defence (p. 86)

Figure 15Z-1 Trilateration

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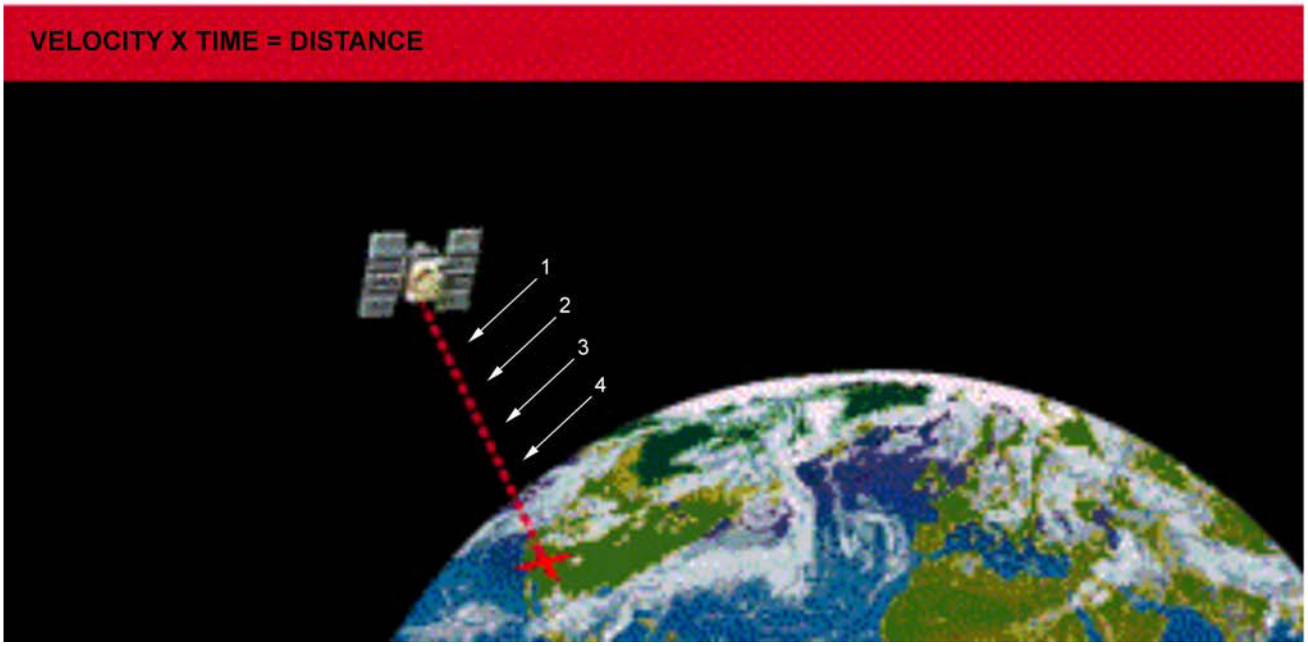
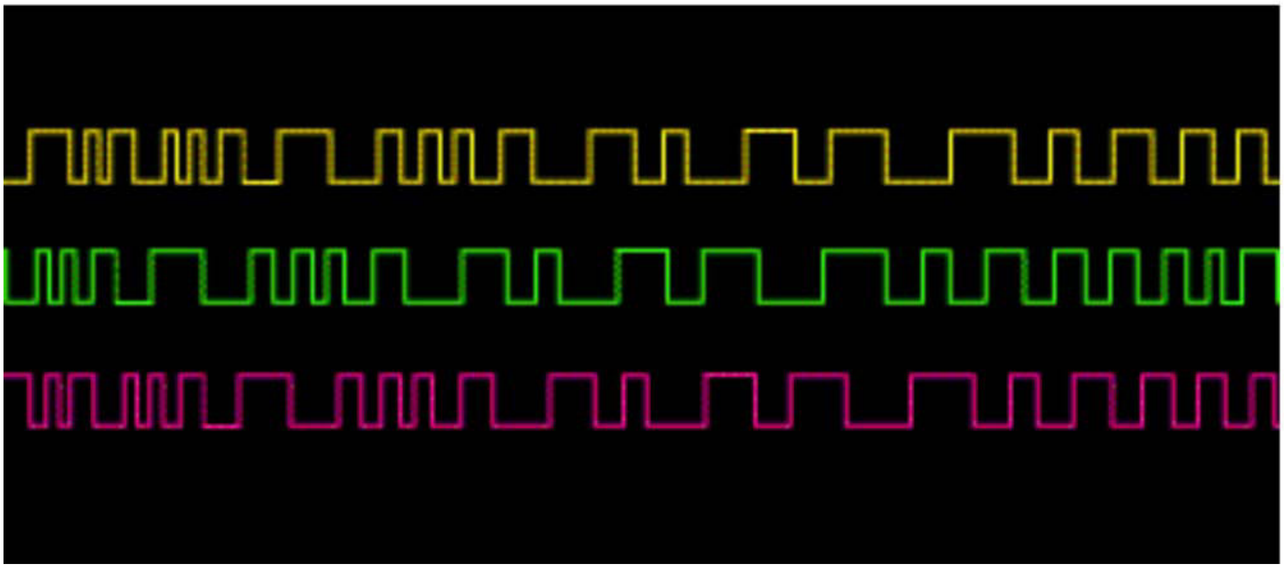
GPS SATELLITES



"GPS Tutorial", Trimple Navigation Limited, 2008, How GPS Works? Copyright 2008 by Trimple Navigation Limited. Retrieved April 11, 2008, from http://www.trimble.com/gps/howgps-triangulating.shtml

Figure 15AA-1 Travelling Down



"GPS Tutorial", Trimple Navigation Limited, 2008, How GPS Works? Copyright 2008 by Trimple Navigation Limited. Retrieved April 11, 2008, from http://www.trimble.com/gps/howgps-triangulating.shtml

Figure 15AA-2 Coded Signals

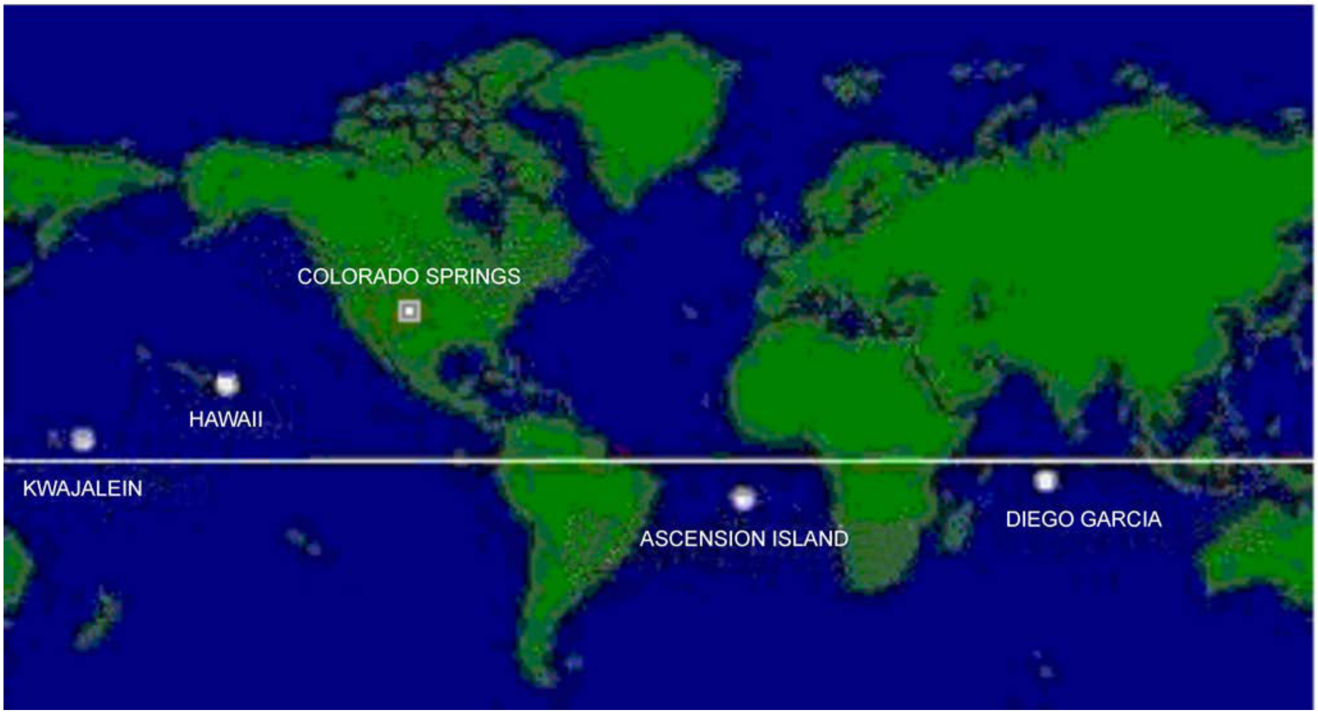
THE CHALLENGE OF TIMING

Timing is tricky.

Precise clocks are needed to measure travel time.

The travel time from a satellite directly overhead is about 0.06 seconds.

The time required to synchronize the receiver's internal coded pulses with the satellite's coded pulses is equal to the travel time.



"GPS Control Segment", Millennium Telecomm Corp (MTC), Control Stations, Copyright 2007 by Phoenix Tree Technology Corp. Retrieved April 15, 2008, from http://ufindit.com/GPS-stations.asp

Figure 15AA-3 GPS Control and Monitoring Stations

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THE MERIDIAN LINE LASER, OLD ROYAL OBSERVATORY, GREENWICH

NMM Royal Observatory, 2008, Meridian Line. Retrieved April 11, 2008, from http://www.nmm.ac.uk/server/show/nav.2904

Figure 15AB-1 The Meridian Line Laser, Old Royal Observatory, Greenwich

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SPACE SHUTTLE *ENDEAVOUR* (STS-118) AFTER UNDOCKING FROM THE ISS

National Aeronautical and Space Administration, STS-118 Build the Station, Build the Future, NASA (p. 54)

Figure 15AC-1 Space Shuttle *Endeavour* (STS-118) After Undocking From the ISS

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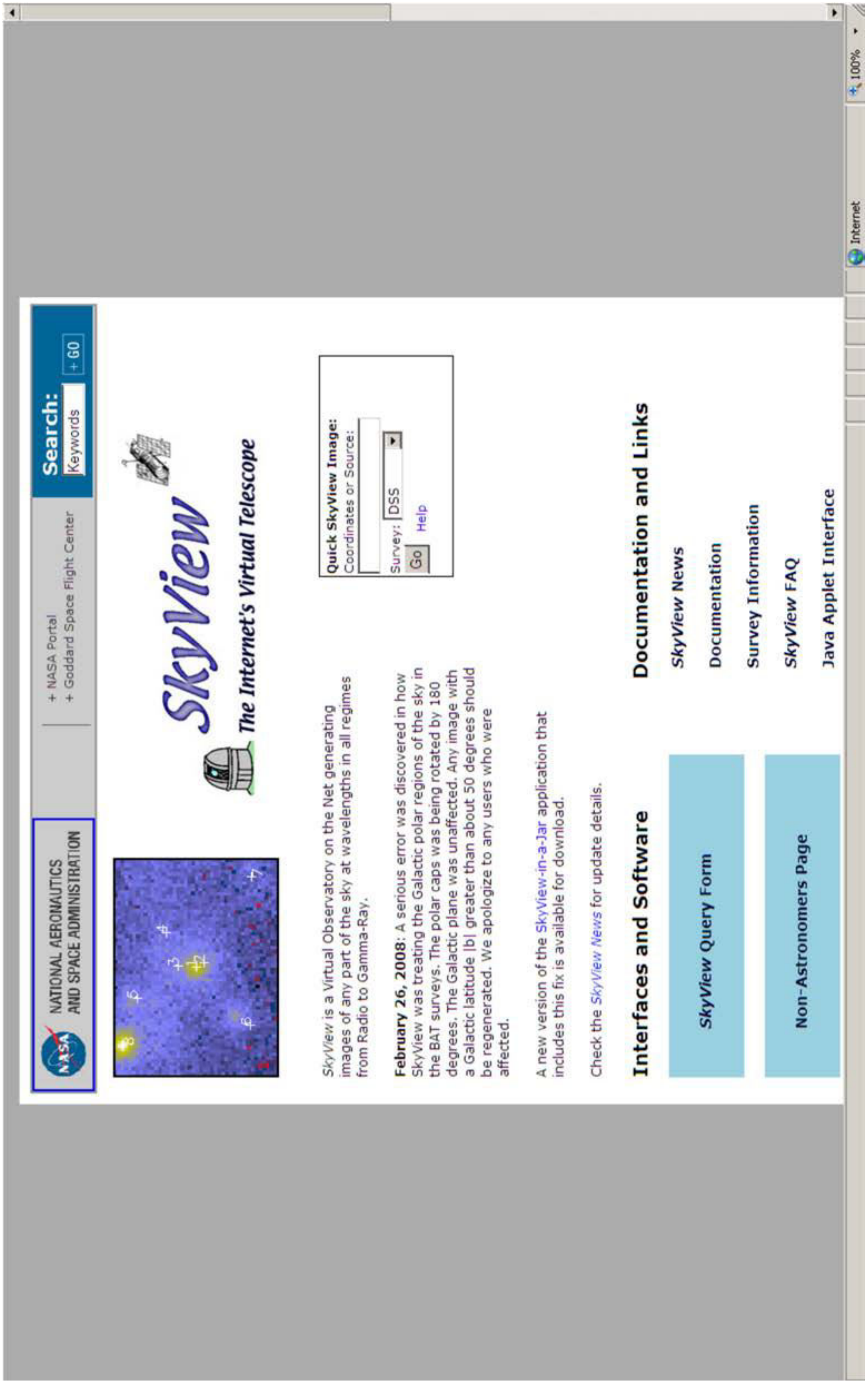
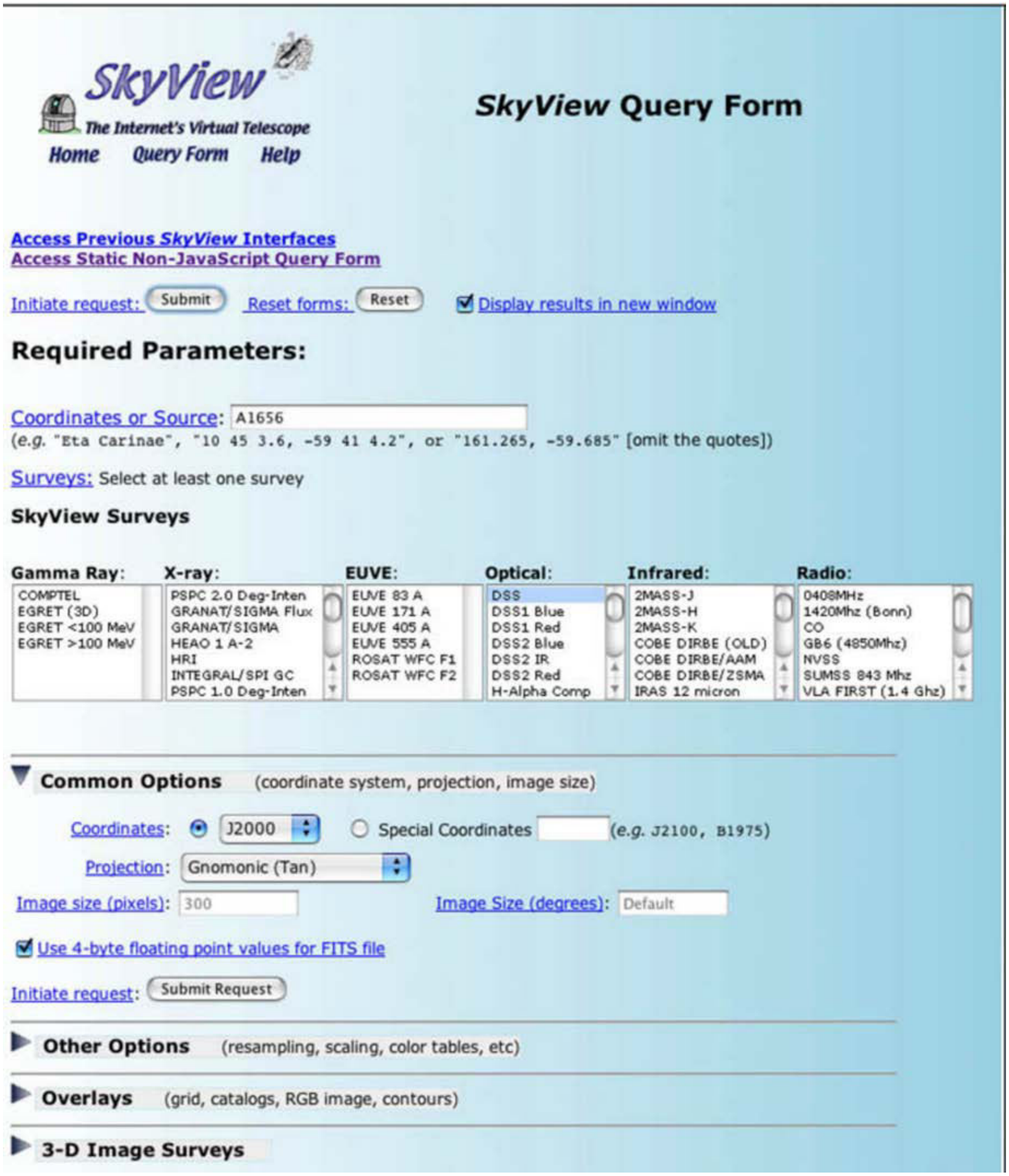
SKYVIEW



NASA SkyView, 2008, “SkyView: The Internet’s Virtual Telescope”. Retrieved March 19, 2008, from http://skyview.gsfc.nasa.gov/

Figure 15AD-1 SkyView Home Page



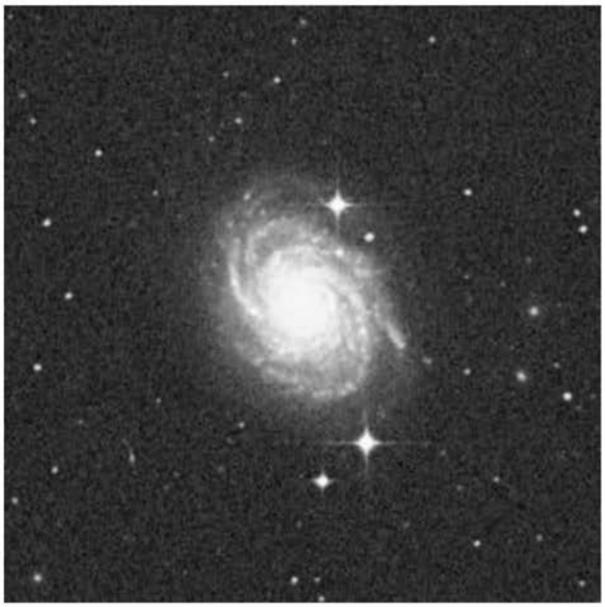
NASA SkyView, 2008, "SkyView: The Internet's Virtual Telescope". Retrieved March 19, 2008, from http://skyview.gsfc.nasa.gov/

Figure 15AD-2 SkyView Query Form

SkyView
The Internet's Virtual Telescope
Home Query Form Help

***SkyView* Images**

Digitized Sky Survey: Original Digitized Sky Survey

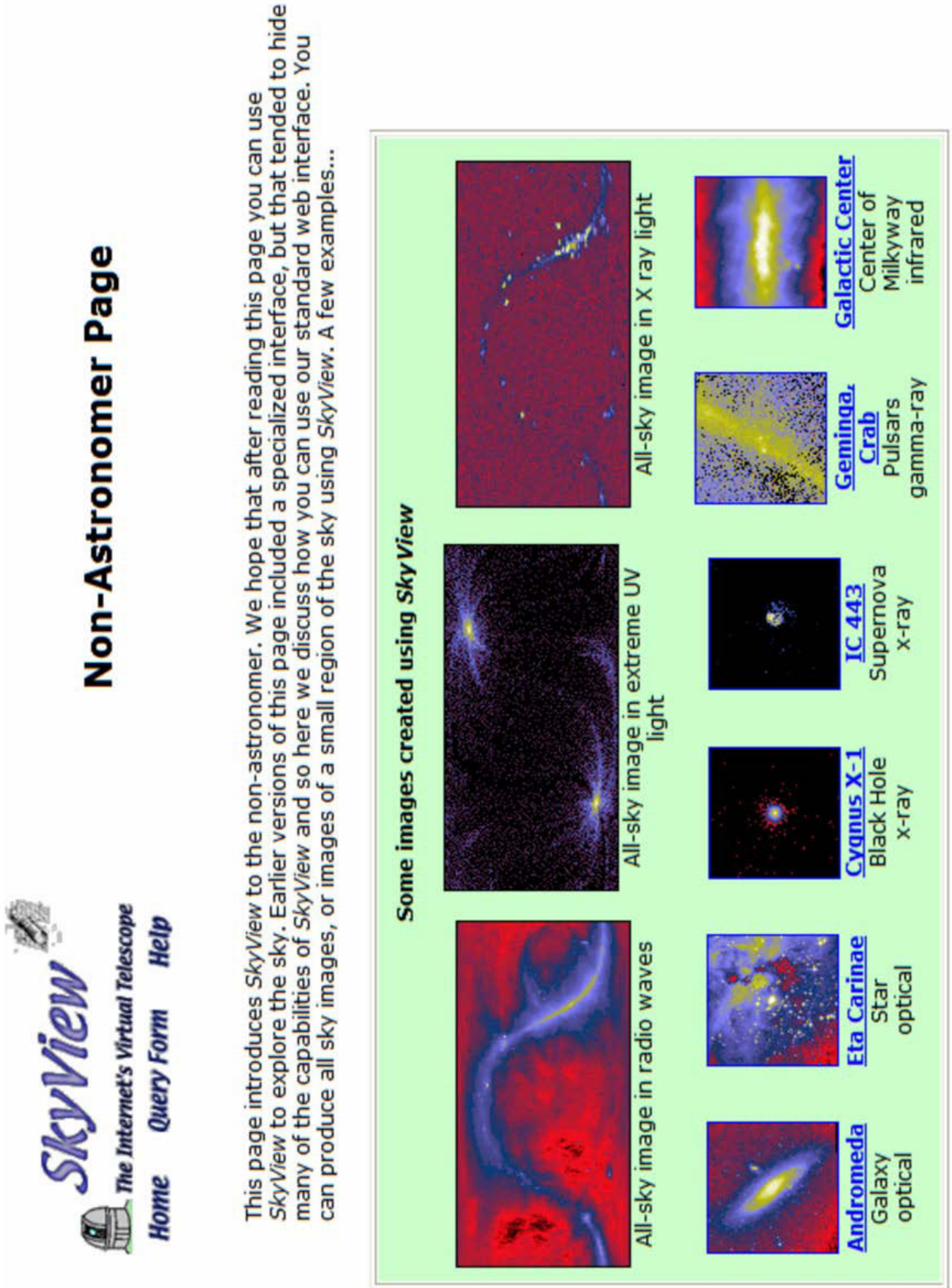


X, Y: 273,3 -> J2000.0: 12 00 09.78 -01 10 10.0

Image color table:
Image scaling: Log, values range from 4406.0 to 18483.0
Image size(degrees): 0.14166666 x 0.14166666
Image size(pixels): 300 x 300
Requested Center: NGC 4030
Coordinate System: J2000.0
Map projection: TanProjecter

NASA SkyView, 2008, "SkyView: The Internet's Virtual Telescope". Retrieved March 19, 2008, from http://skyview.gsfc.nasa.gov/

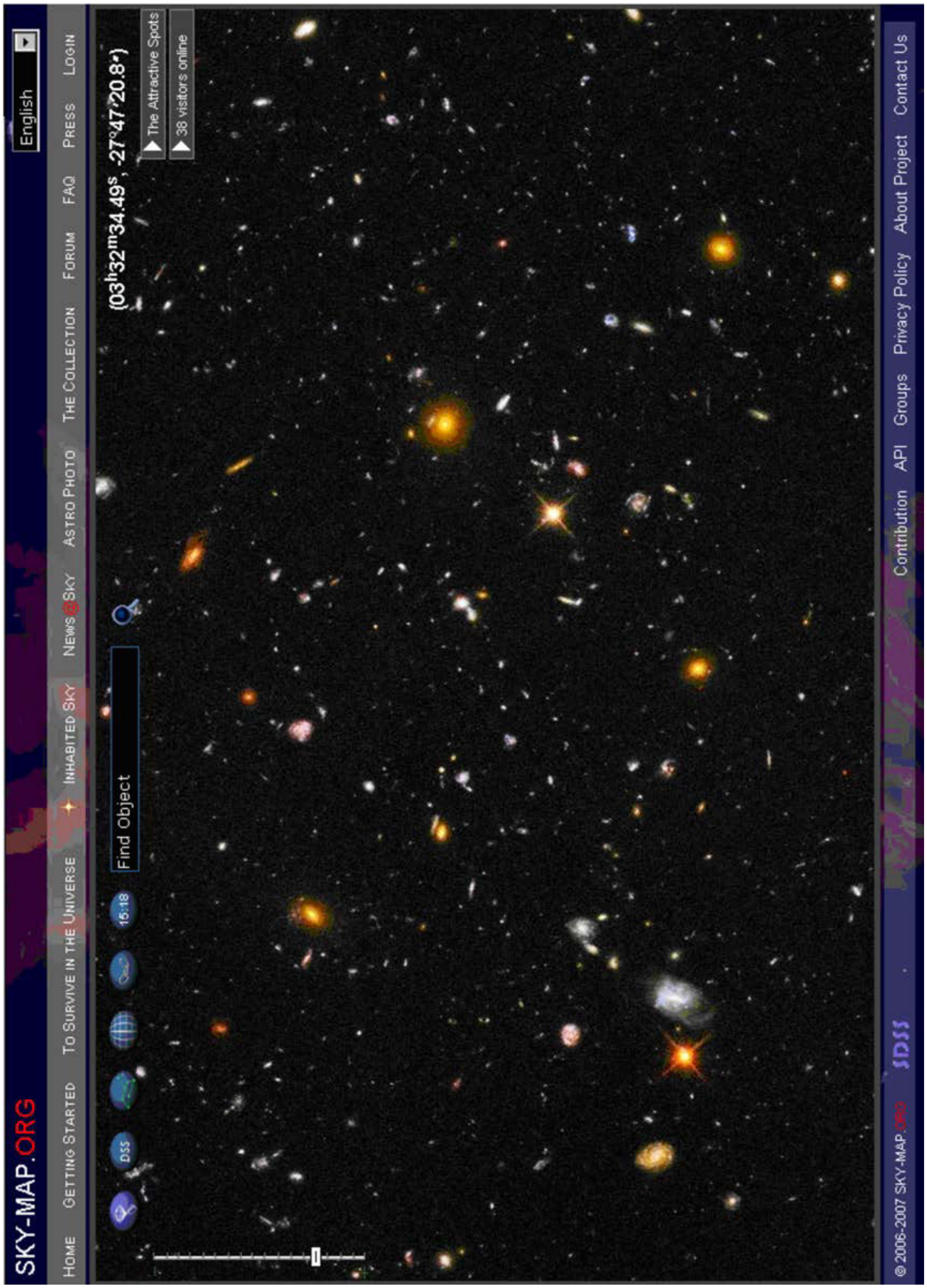
Figure 15AD-3 SkyView Image



NASA SkyView, 2008, "SkyView: The Internet's Virtual Telescope". Retrieved March 19, 2008, from http://skyview.gsfc.nasa.gov/

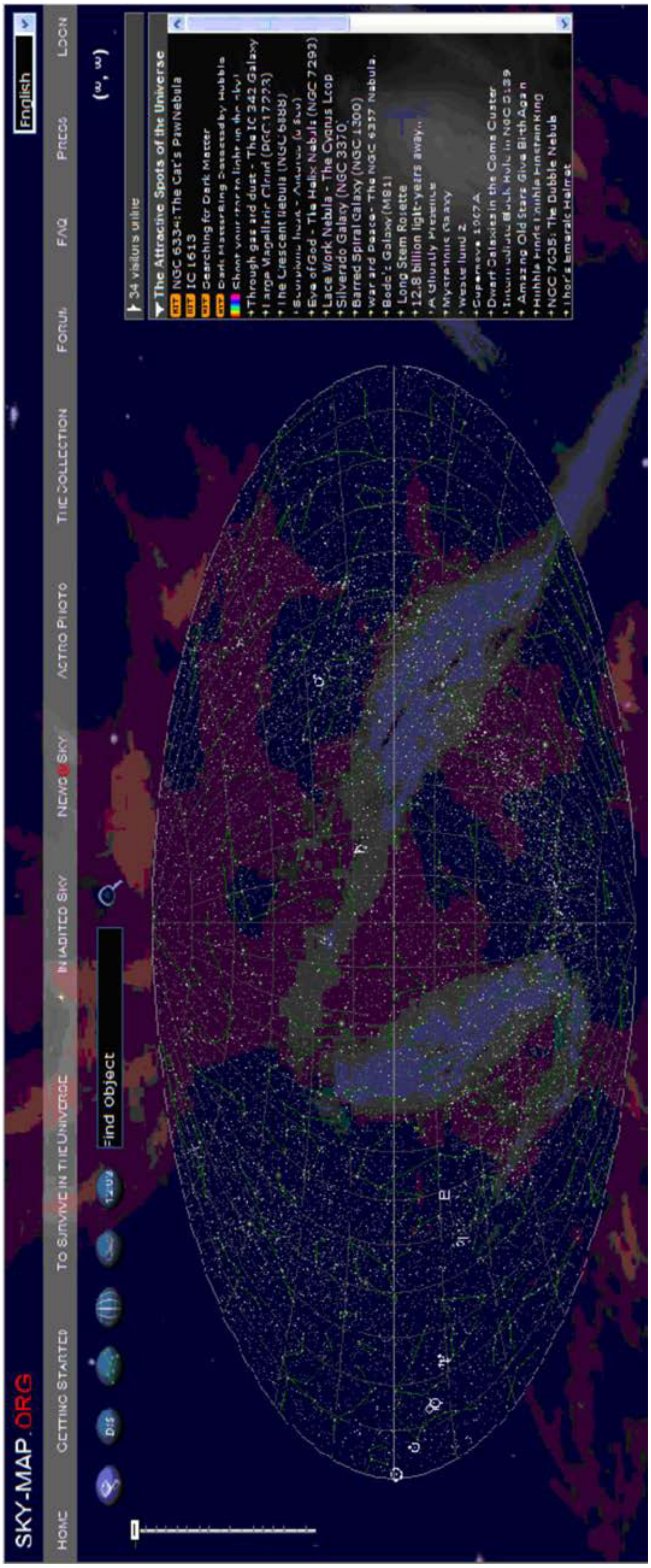
Figure 15AD-4 SkyView Non-Astronomers Page

SKY-MAP.ORG



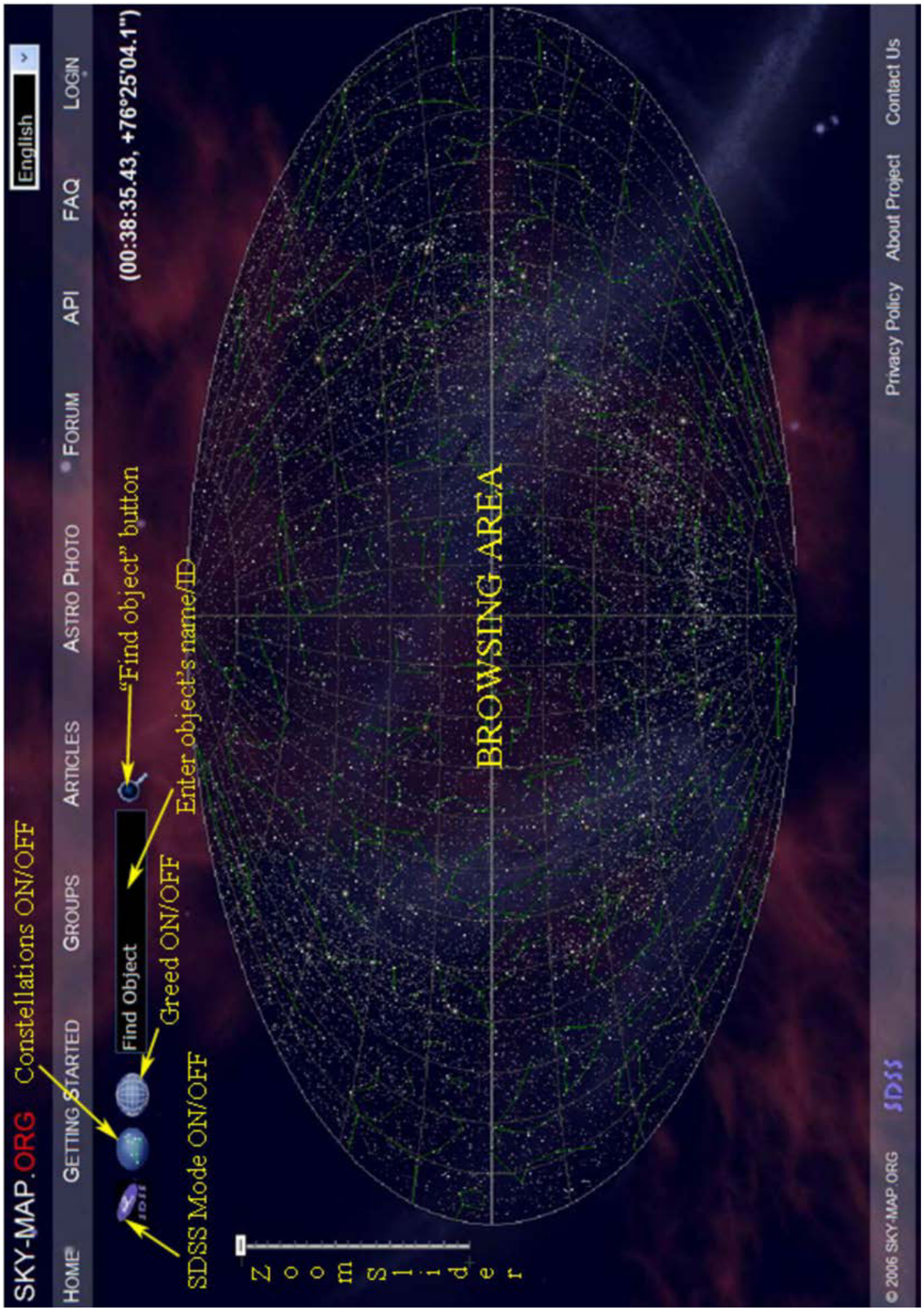
SKY-MAP.ORG, 2008, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15AE-1 The View From the Hubble Space Telescope



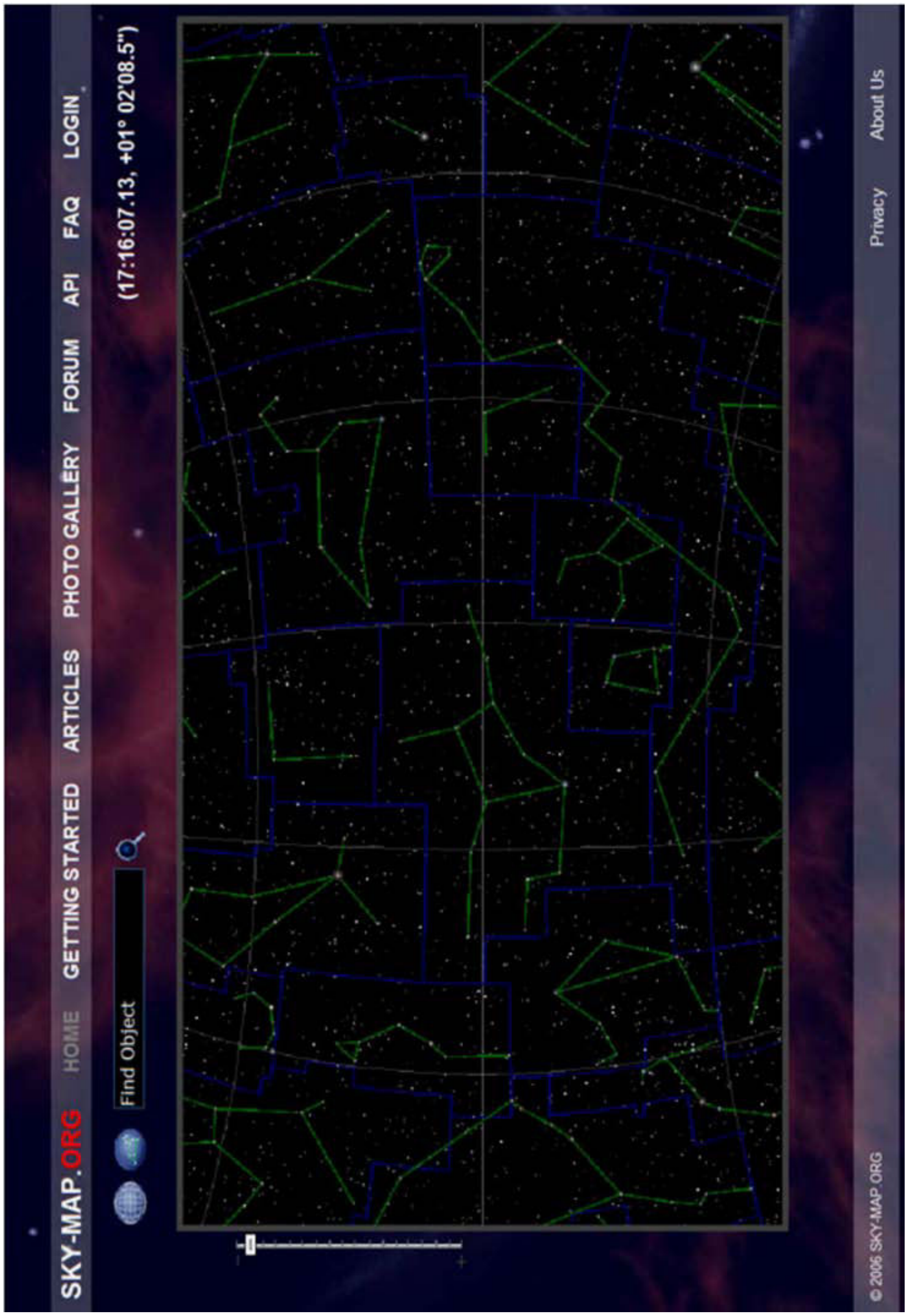
SKY-MAP.ORG, 2008, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15AE-2 SKY-MAP.ORG Home Page



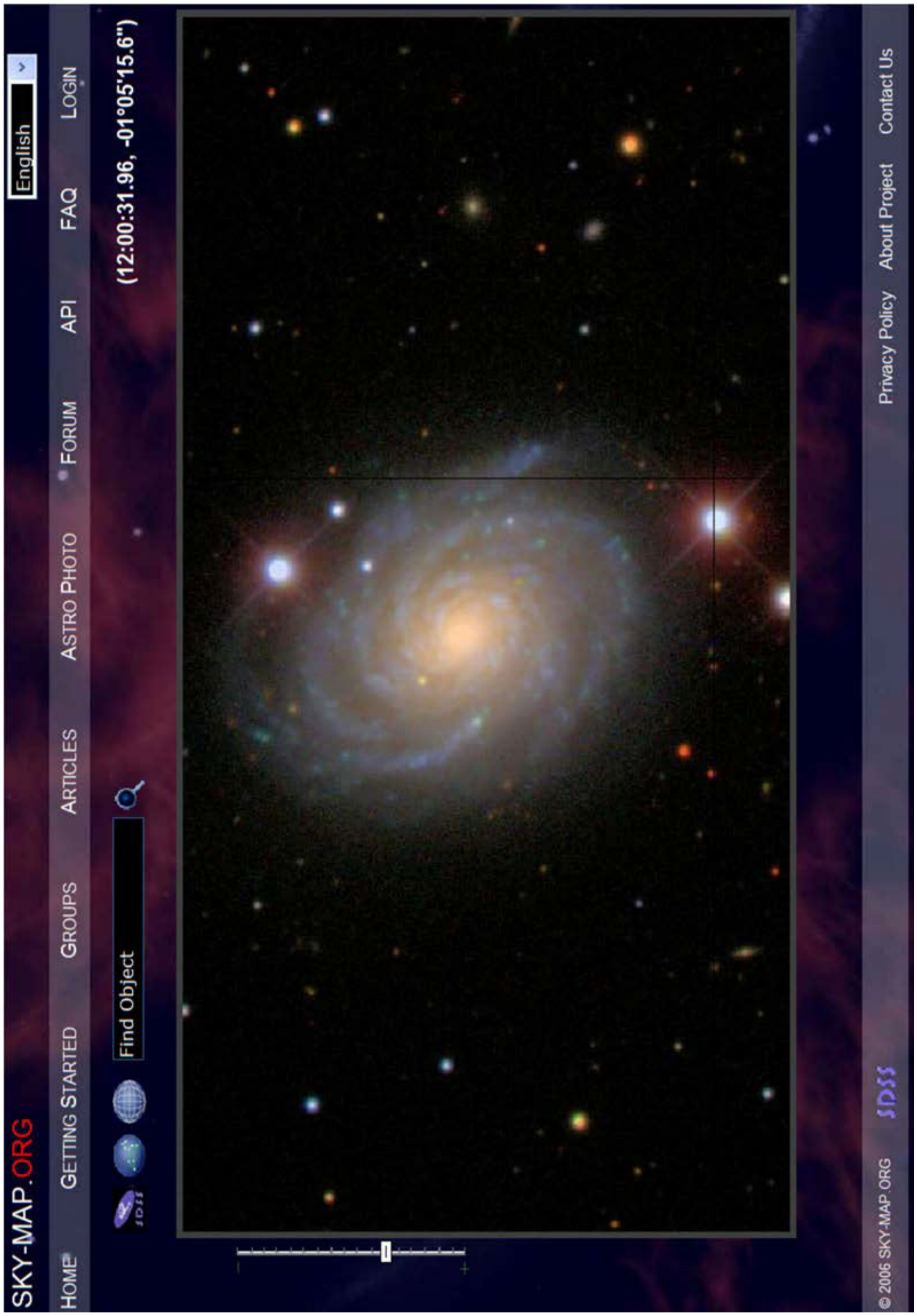
SKY-MAP.ORG, 2008, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15AE-3 SKY-MAP.ORG Instruction Page



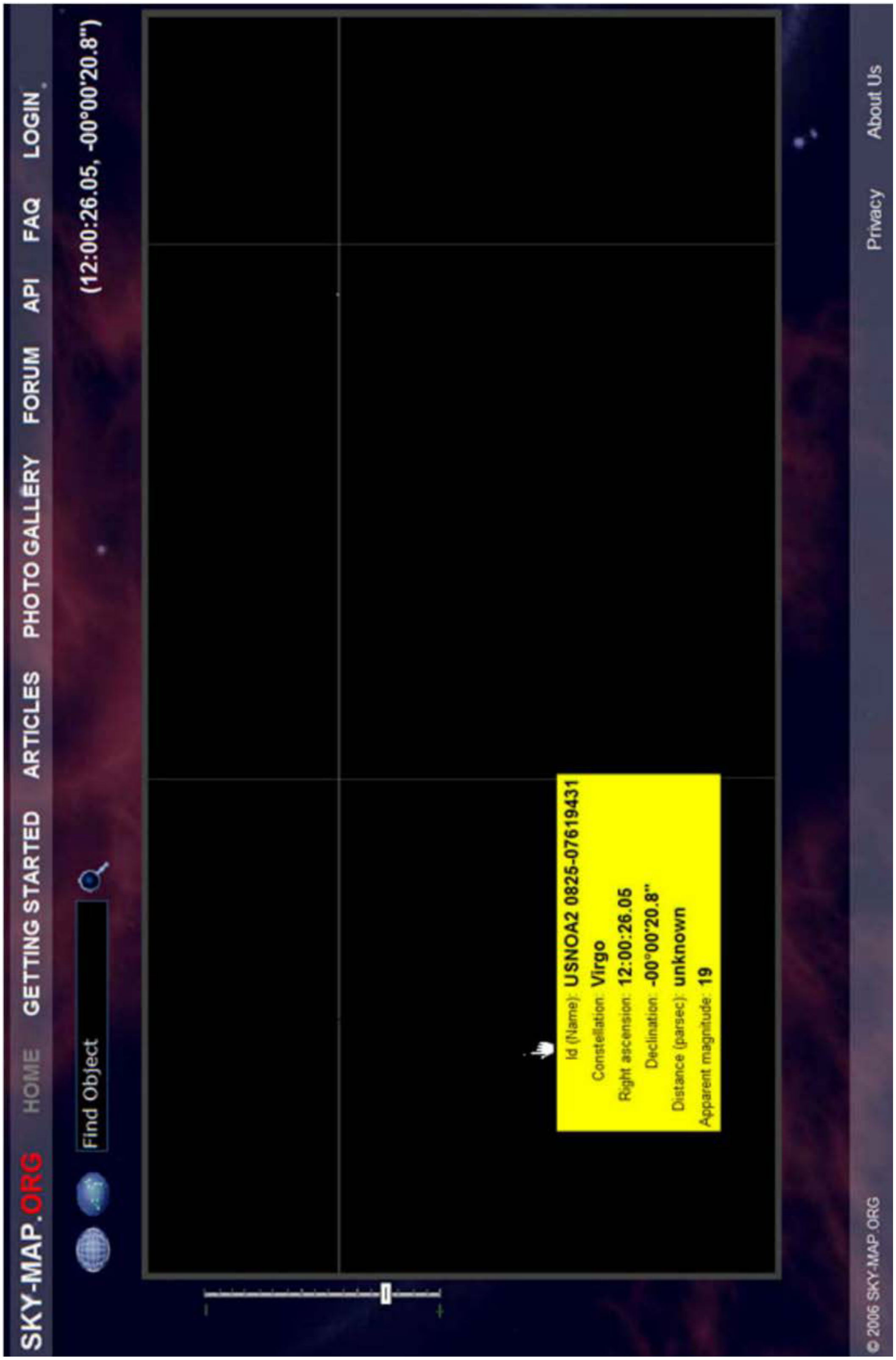
SKY-MAP.ORG, 2008, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15AE-4 SKY-MAP.ORG Normal Mode



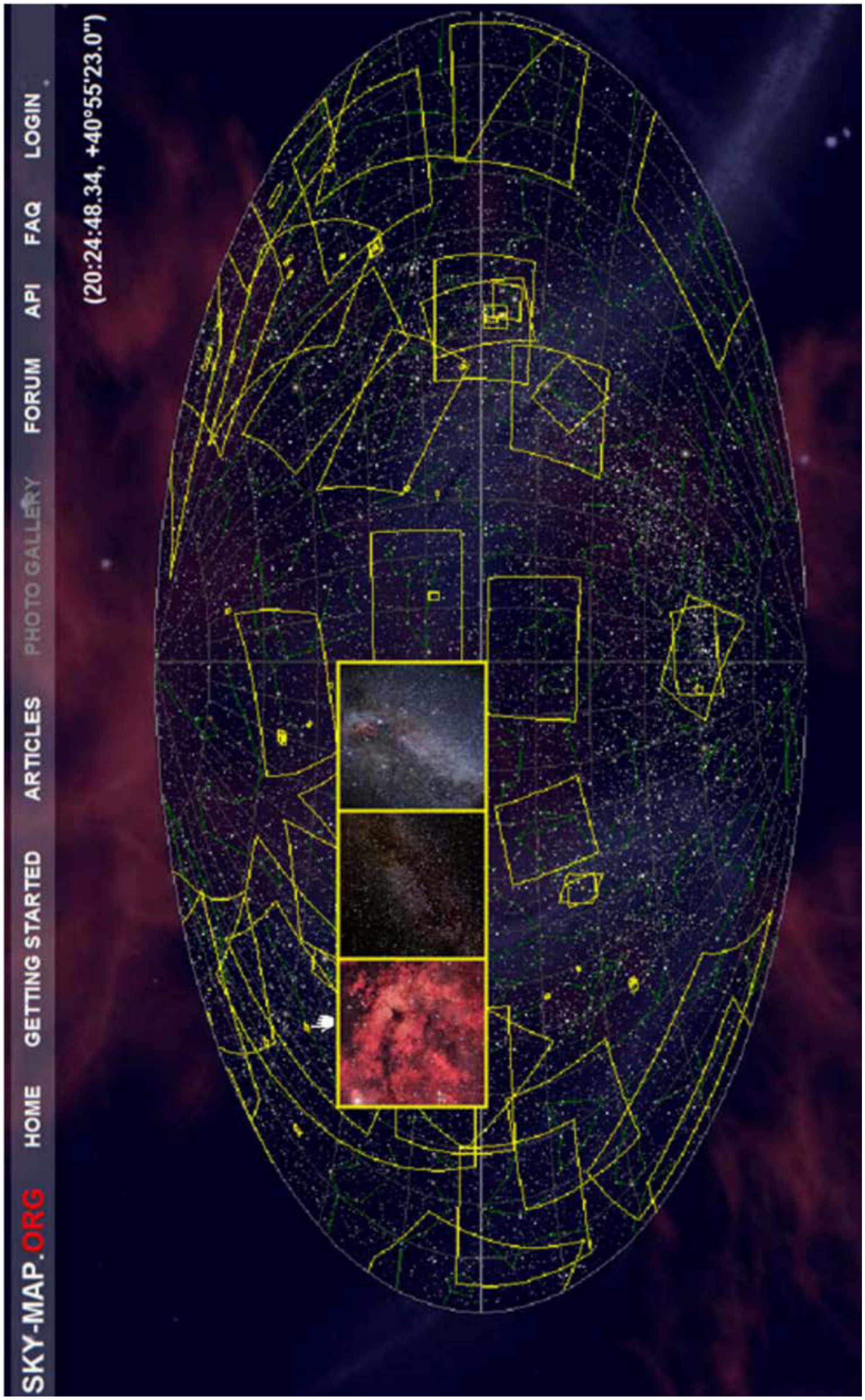
SKY-MAP.ORG, 2008, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15AE-5 Spiral Galaxy in SDSS Mode



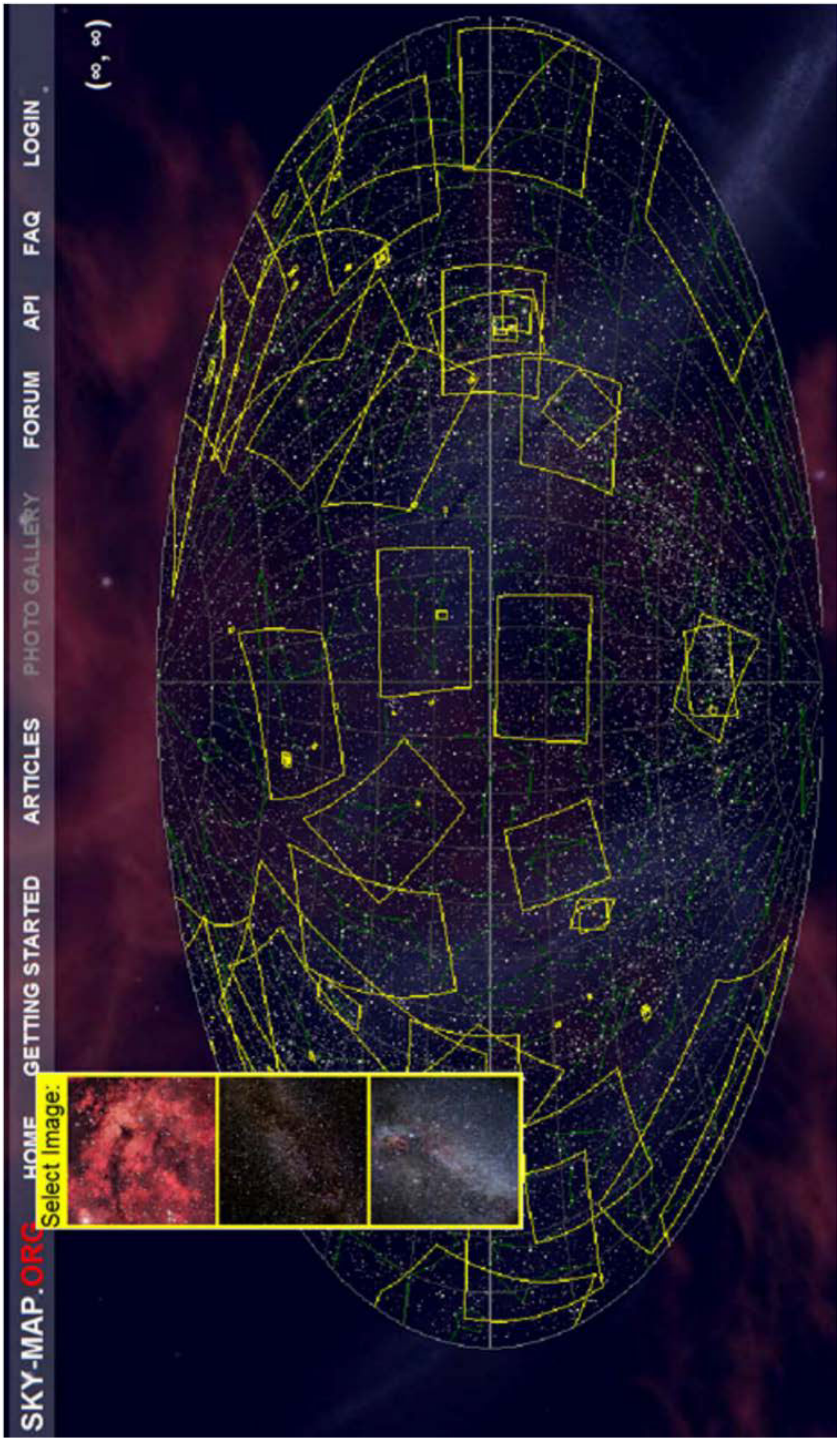
SKY-MAP.ORG, 2006, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15AE-6 Magnitude 19 in Virgo



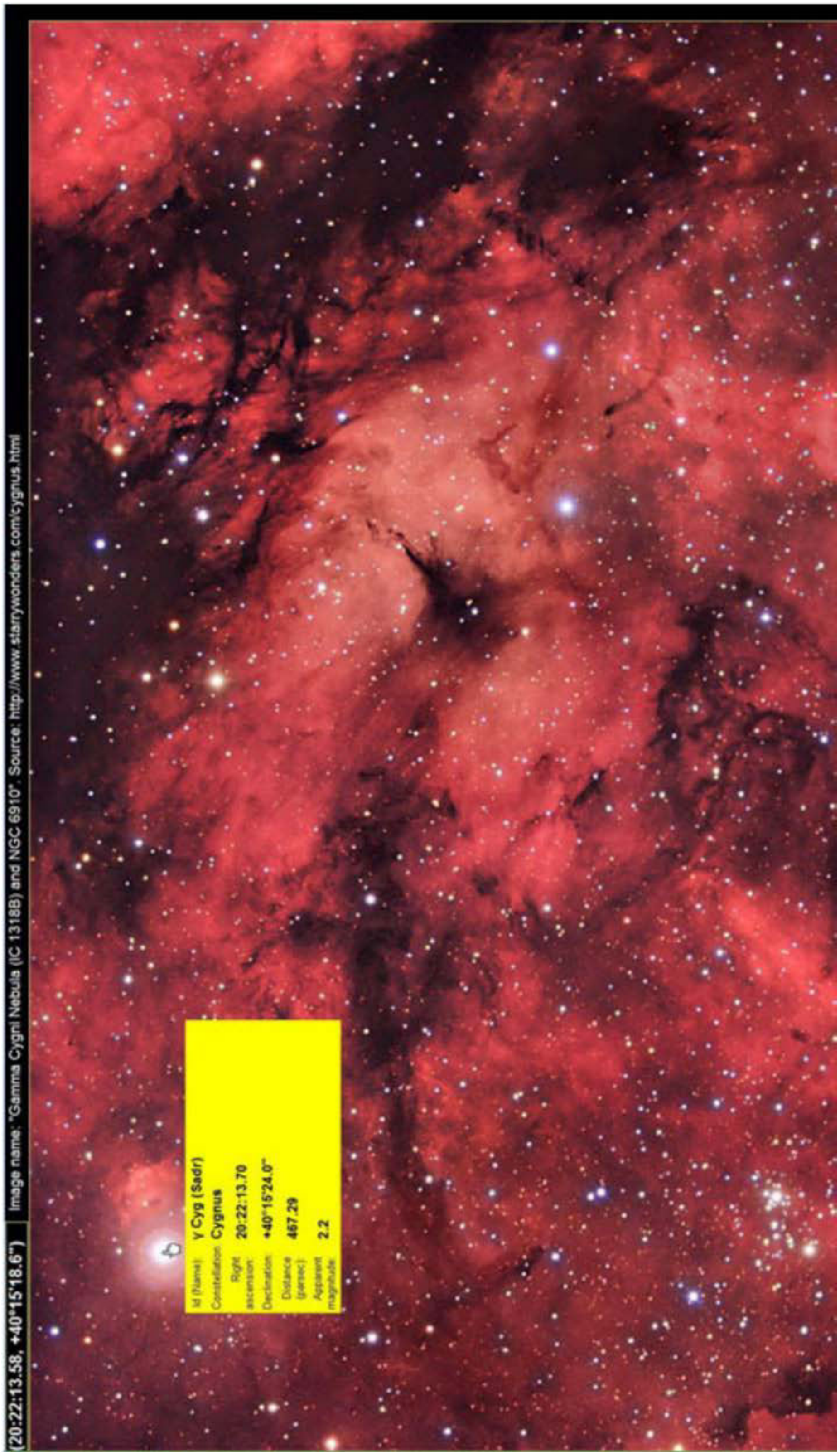
SKY-MAP.ORG, 2006, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15AE-7 SKY-MAP.ORG Photo Gallery



SKY-MAP.ORG, 2006, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15AE-8 Image Selection



SKY-MAP.ORG, 2006, "SKY-MAP.ORG". Retrieved March 19, 2008, from http://sky-map.org/

Figure 15AE-9 Gamma Cygni Nebula Image Selected

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ASTRONOMY BASICS

For background information regarding many aspects of astronomy, Canada's National Research Council (NRC) Herzberg Institute of Astrophysics (NRC-HIA) offers Astronomy Basics at http://hia-iha.nrc-cnrc.gc.ca/public/astr_e.html.

Astronomy Websites of Interest

- Sloan Digital Sky Survey (SDSS) at http://www.sdss.org/background/
- SKY-MAP.ORG at http://sky-map.org/
- NASA's SkyView at http://skyview.gsfc.nasa.gov/
- NASA satellite sighting opportunities data at http://spaceflight.nasa.gov/realdata/sightings/
- Explore the Night Sky with Canada's National Research Council at http://www.nrc-cnrc.gc.ca/eng/education/astronomy/constellations/html.html

HINTS FROM THE LESSON EO C340.10 IDENTIFY ONLINE STARGAZING PROGRAMS

In this lesson SKY-MAP.ORG found galaxy NGC 4030 in constellation Virgo.

NGC 4030 is at celestial coordinates:

- Right ascension: 12 hours 00 minutes 23.40 seconds
- Declination: -01°06'03.0"

When online, this photographic plate can be found by entering the name NGC 4030 into the "Find Object" text box or by entering the coordinates as right ascension followed by a comma and then declination.

This celestial coordinate data is entered into the "Find Object" text box as one data field: 12 00 23.40, -01 06 03.0.

If coordinates are entered, however, considerable magnification must be applied to see NGC 4030. At this scale, it is magnitude 0 in the real sky, appearing as a bright star.

Star brightness is called magnitude. The lower the magnitude, the brighter the object. The brightest star visible in the night sky is Sirius, classified as magnitude −1.

Sirius, the brightest star, is found at coordinates 06 45 08.90, -16 42 58.0 in Normal Mode.

SDSS does not yet cover this part of the sky, but many astro photos of Sirius can be located through Sirius' Basic Information Window (BIW) by clicking on Sirius when its BIW is open.

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