INTRODUCTION (2 min)

CIVIL AIR PATROL
INTRO TO SPACE
STK LESSON PLAN ONE:
ORBITAL MECHANICS

ATTENTION:

Now that we have showed you just enough of orbital mechanics to thoroughly confuse you, we are going to look at the concepts in a different way.

MOTIVATION:

To do this, we are going to show you the exciting Satellite Toolkit application. Sometimes, it is much easier to understand complex concepts visually. So we are going to demonstrate the orbital elements using Satellite Toolkit in order to make this complex subject easier to understand.

OVERVIEW:

1. Understand the elements that define an orbit.
2. Understand how each orbital element influences the satellite's ground track.
3. Understand how these elements relate to defining missions.

TRANSITION: Let's review some key areas of Orbital Mechanics

BODY (2 hours)

PRESENTATION.	
A. **PART I – OVERVIEW** This portion of the lesson plan will demonstrate the orbital mechanics concepts just presented using STK. Remember, orbital mechanics is the study of satellites in orbit. The lesson will review the six orbital elements which uniquely define orbital characteristics. In addition, this lesson will demonstrate the orbital element affects on ground tracks.	
(1) **Orbital Elements** a) **SIZE:** 1) The *semi-major axis* determines the size of the orbit. The term **a** defines the semi-major axis.	*QUESTION: What is the definition of a semi-major axis??* (One half the distance between perigee and apogee) *QUESTION: What is perigee?? Apogee??* (Point in an orbit at which the satellite is closest to the earth/furthest away from the earth. The size of the orbit determines how long the satellite takes to make one pass around the earth. The time required for a satellite to complete one orbit is called orbit period.
b) **SHAPE**: 1) *Eccentricity* is defined "as the amount the orbit deviates from the circular." The eccentricity term, **e**, is measured from zero, a perfect circle, to one for elongated earth orbits. An elongated earth orbit is an eccentric orbit.	
	QUESTION: What happens if the eccentricity value is greater than one?? (This describes an orbit that leaves the earth's gravity)
	Visualize a large rubber band around the earth. The rubber band represents the orbit. As the rubber band is stretched it becomes elongated, thus, more eccentric. As the rubber band is released, it becomes more circular or less eccentric.

c) **ORIENTATION**:	*QUESTION: What is the definition of inclination??*
1) *Inclination.*	*Inclination* is defined as "the angular distance between the equator and the orbit plane." It is commonly referred to as the tilt of the orbit with respect to the equatorial plane. An inclined plane allows the satellite to travel to a maximum north and south latitude equal to its inclination. Latitude is the "distance of a point on the earth's surface from the equator.
2) *Right Ascension of the Ascending Node* (RAAN).	*QUESTION: Can anyone remember what Right Ascension is??* It is the angular measurement from the point of Aries, a star. The direction is measured eastward along the orbital plane to a point where the orbit crosses the equator going south to north called the ascending node." The term describes the "orientation of the orbital plane with respect to the ascending node." The earth is spinning within the geocentric coordinate system, thus, making it difficult to establish a constant point from which to measure. Consequently, RAAN is used to measure a satellite's position from a relative stationary point called Aries.
3) *Argument of Perigee*	*Argument of perigee* is "the angular distance between the ascending node in the direction of a satellite's motion, to the point of perigee on the orbital path." In effect, you are selecting where the perigee point is placed. The perigee point is the point of the orbit closest to the earth. As well, it is where the satellite travels the fastest in its orbit.
4) *True anomaly*	*True anomaly* is the "angle distance of perigee to the position of the satellite in the direction of the satellite's motion." The significance of the term is that it pinpoints the satellite's exact position in the orbit. True anomaly is never constant.
	QUESTION: Why?? (Because the satellite is always moving!)

Defining an orbit by its classical elements not only uniquely defines an orbit, but also describes the satellite's location points in relation to the surface of the earth, called ground tracks.	
2) **Ground Tracks**	The trace of the vehicle subpoints on the earth's surface as it orbits around the earth is called a ground track. In other words, the ground track is the satellite's orbital path projected onto a two-dimensional flat map. The characteristics of the ground track are derived from orbital elements. Described below are the orbital elements effects on ground tracks.
a) *Semi-major axis.*	The semi-major axis influences the ground track's repeating pattern. The semi-major axis parameter determines the size of the orbit, and thus, the time it takes a satellite to complete one orbit. For example, a satellite with a smaller semi-major axis, like a LEO satellite, completes each pass over a different spot over the earth. This is due to the earth rotating at a slower speed than the LEO satellite completing its orbit. Consequently, the LEO ground track reflects successive ground tracks shifting to the west. In contrast, a satellite with a larger semi-major, like a GEO satellite, moves at the same speed as the earth's rotation. As a result, the GEO ground track projection appears as a dot on the surface of the earth.
b) *Inclination.*	Inclination influences a ground track by defining how far north or south in latitude the satellite will travel. In other words, the ground track will trace out an orbit with the north and south latitudes equivalent in values to the satellite's inclination.
c) *Eccentricity*	Eccentricity affects the ground track's symmetry. For example, a circular orbit will produce a symmetric sine wave pattern. In contrast, a HEO will produce a non-symmetric pattern where the apogee point will be a smaller wave compared to the perigee point.

d) *Right Ascension of the Ascending Node (RAAN).*	RAAN affects where the ascending node crosses the equator.
e) *Argument of Perigee*	The affects of argument of perigee on the ground track shows how much earth surface area is covered between the ascending and descending nodes.
B. PART II - STK SCENARIOS This portion of the lesson plan illustrates the satellite concepts you just learned about. To do this, you will run six self-guided scenarios using STK/VO software. Each scenario will help you visualize the characteristics associated with the six orbital elements. **REFER TO CHAPTER ONE, PART II - FOR STK SCENARIOS ONE THRU SIX AT ATTACHMENT** *Recommend handing out the attachements to the students and let them accomplish the scenarios at their own pace.*	
C. PART III - STUDENT PROBLEM This portion of the lesson plan provides an opportunity for you to apply the concepts you have learned in Part I and Part II by solving a problem.	

Problem	You work for a large television affiliate in the year 2000. You are very excited to learn that you will be the chief coordinator for bringing live television to the U.S. coverage of the 2000 Summer Olympics in Sydney Australia. However, due to last minute notice, you discover that all satellite links in the area have already been leased. You have informed your supervisors of the problem and have been given money to launch a new satellite in orbit. Funds are limited; thus, a geostationary orbit is out of the question. In addition, the TV station is willing to accept short periods of gap in the coverage. What type of orbit will best suit your needs to ensure you have coverage of the summer Olympics? Describe the orbit in terms of the 6 elements discussed in this lesson. Use STK to illustrate your solution.
Proposed Solution **REFER TO CHAPTER ONE, PART III - FOR STK PROPOSED SOLUTION, AT ATTACHMENT**	The constraints of the problem prevent you from using a GEO satellite orbit. However a HEO satellite provides the next best type of orbit to provide long periods of coverage. Additionally, since continuous coverage is not required, a HEO satellite would meet your needs. To visualize the proposed solution load the file **scenario/lesson3/student_problem** and proceed with the following steps. The terms to describe the orbit are as follows: 1. Semi-major axis:: 26553 km 2. Eccentricity: .7 3. Inclination: 45.0 degrees 4. RAAN: 71.0 degrees 5. Argument of perigee: 270.0 degrees 6. True anomaly: 0.0 degrees
D. PART IV - SUMMARY This lesson illustrated several points. First, orbits are defined by six orbital elements which dictate the orbit's size, shape and orientation. Second, these orbital elements determine the satellite's ground track pattern. Ground tracks are a projection of an orbit onto a two-dimensional map aiding in determining a satellite's geographic position. Orbit characteristics determine how well a satellite can meet its mission objectives.	
TRANSITION: Are there any questions?	
BREAK !! You have completed Scenario One.	