COMMUNICATION LINK ANALYSIS FOR ION-F MISSION
(STK supports comm. study and analysis)

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The Ionospheric Observation Nanosat Formation (ION-F) is a student project involving engineering teams at four universities. The objective is to build and fly a constellation of three 20 kg satellites named USUSat, HokiSat, and DawgStar, as shown in Figure 1.

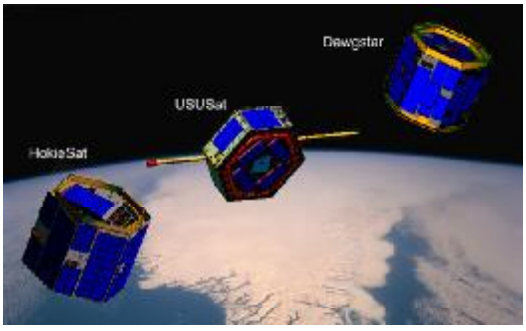

Figure 1: ION-F Constellation.

The universities involved are Utah State University (USUSat), Virginia Polytechnic Institute (HokiSat), University of Washington and Cornell University (DawgStar). The program is under NASA Goddard direction but was started as part of the AFSOR/DARPA University Nanosatellite Program. It has progressed with support from industry, NASA, the Air Force Research Labs, and the Air Force Space Test Program. The principal objective has been to give students "a hands" on experience with spacecraft systems and systems engineering thus better preparing them to work in the space industry. The ION-F satellites are a combination of technology demonstrations including pulse plasma thrusters, low-power, radiation tolerant computer systems, and highly integrated science-craft. As a constellation the spacecraft will demonstrate autonomous formation flying and make multi point measurements in the ionosphere of electron density irregularities. These irregularities effect radio wave propagation including communications, navigation, and the GPS System. Navigation and inter-satellite communication will be provided by an onboard GPS/Crosslink system developed by the John Hopkins Applied Physics Lab. The constellation is designed to be launched from the shuttle during an upcoming space station servicing mission.

Analytical Graphics has partnered with the universities on ION-F by providing STK for the students use. STK has an enormous analytical and visual capability that has helped in all levels of systems engineering throughout the various phases of the program. For instance the STK-Pro Lifetime Orbit Propagator has been used to compute the lifetime of USUSat based on it mass and spacecraft attitude (cross sectional area). This data is shown in Figure 2. Students have directly used STK graphs and reports, have imported the data into Excel for plotting, or have used it as the driving inputs for MATLAB simulations as in Figure 2.

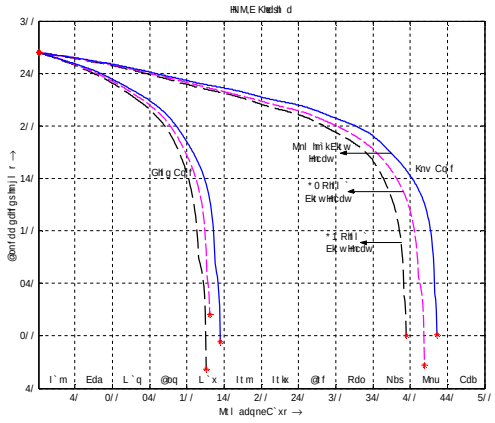

Figure 2: ION-F lifetime as computed using lifetime module of STK assuming a starting date of 1st Jan 2003.

Students have used STK-Pro and the STK/Comm. modules to determine systems level requirements and verify performance of ION-F communications systems. A line diagram for the ION-F communication links is shown in Figure 3.

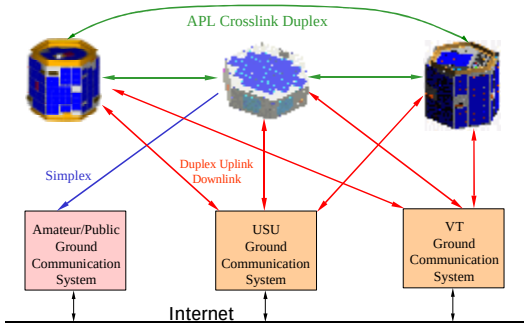

Figure 3: ION-F communication system.

The satellites share a joint set of frequencies for uplink and crosslink communications but separate S-band frequencies are used for downlink to ground stations located at Utah State University and Virginia Tech. An amateur radio experiment, reporting spacecraft position, will be included on USUSat. STK has been used to compute access and time to next contact under various orbital parameters. This, along with data collection rates onboard the spacecraft has been used to size the required downlink telemetry rates and to size the on board storage for the spacecraft. Graphs of this data are presented in Figure 4.

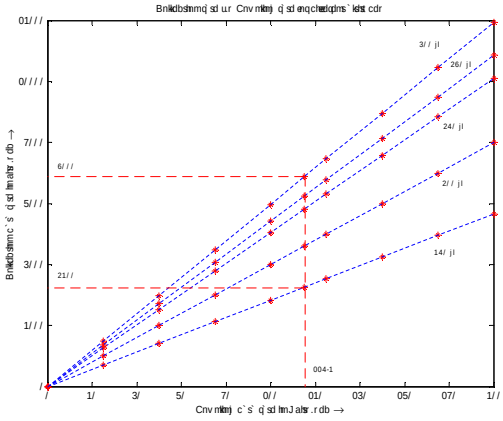

Figure 4: Collection rate v/s downlink rate for different altitudes.

The state of the telemetry buffer over multiple orbits for various RAAN's is presented in Figure 5 where the 'o' shows the state of the buffer before the pass begins, the '*' is the amount of data down linked in the pass, and the 'x' is the data remaining in the buffer after the overpass.

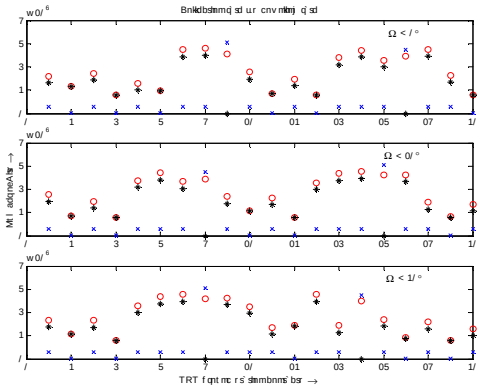

Figure 5: Telemetry buffer states for contacts with USU ground station.

The STK/Comm. module has been used to compute antenna noise temperatures, patterns, and gains for both the spacecraft and ground station for sample overpasses. These calculations include the effects of spacecraft attitude and ground station pointing. A sample of this is the antenna pattern for the ground station S-Band Helical antenna as shown in Figure 6.

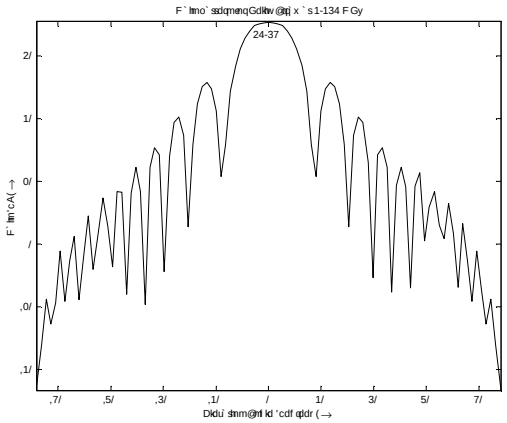

Figure 6: The gain pattern for the helical array.

The STK/Comm. module has also been used to compute the bit error rate (BER), Eb/No, for the up and down links based on transmitter power, data rates, and receiver noise temperatures. Reports and plots have been generated using this module for various periods of time and spanning a large set of "what if" conditions for distribution among the student engineering teams. A sample of this is shown in Figure 7 where Eb/No are plotted against various elevation angles for a ground station overpass.

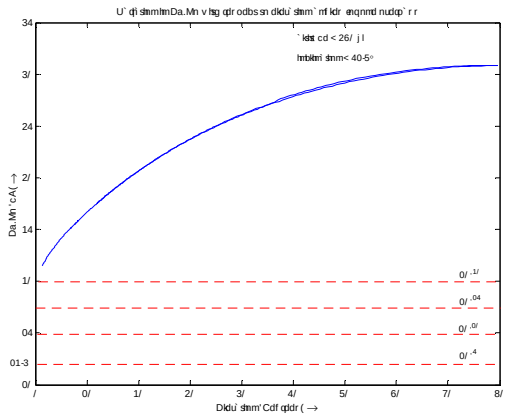

Figure 7: Variation of Eb/No for different elevation angles.

Utah State University has been using STK in space engineering courses since 1993 and was one of the first universities to participate in the AGI Educational Partners program. It has been an invaluable tool in helping students to visualize satellite motion and assisting them with the resulting systems engineering issues.