GSAW 2018 Tutorial D:

Introduction to Satellite Communications

Length: Half day

Overview:

1 Introduction to Satellite Communications Course Outline

This half-day course provides attendees an introduction to digital satellite communications with a focus on the telemetry and command paths. Attendees will follow the flow of satellite telemetry and commands between the space-vehicle and the operator. Each step in the path (spacecraft, space link, antenna site, ground network and control center) is described; areas of complexity discussed; criteria for architectural decisions are highlighted; and technology trends are presented.

The class is interactive, with students participating in demonstrating several of the key concepts. In the second half of the session, students divide into smaller groups. Each group is given a set of high-level requirements and develops a ground system design which they present to the class.

The course is designed for approximately 30 students. Students should be familiar with the space domain and have a basic understanding of satellite operations. Upon taking the course, students will have an understanding and appreciation of the ground and space communication links and the complexities involved.

1.1 Introductions & Architectural Overview

This section includes a brief overview of the typical end-to-end system architecture, including both the space and ground links. The introduction highlights how different missions and their orbit characteristics drive decisions on the satellite communications links and associated ground system design.

1.2 Telemetry Path

The main part of the tutorial begins by following satellite telemetry points from the spacecraft to the operator on the ground.

1.2.1 Onboard the Spacecraft

This section includes a brief discussion of how the telemetry is commonly assembled, what data formats (TDM, CCSDS) are commonly used and design considerations such as Forward Error Correction (FEC) and when to add encryption.

1.2.2 Space Link

This section introduces basic concepts regarding the choice of waveform, bandwidth, path loss and noise. The focus is on how this impacts the digital data by introducing errors, latencies and changes in bit rate. A high-level overview of waveforms, error correction, and encodings is provided.

1.2.3 Antenna Site

This section begins the process of 'removing' the layers created on board the satellite. An overview of the equipment commonly found at an antenna site, including antennas, frequency converters, receivers, demodulators & bit synchronizers, is given along with descriptions of the signal & data processing performed. Technical considerations regarding topics such as time-data-correlation and the applicability of standards such as CCSDS and OMG's GEMS specification are discussed.

1.2.4 Ground Network

In this section, attendees will receive an introduction to the common ground networks used (WAN, AFSCN etc) and associated protocols (SLE, TCP, PGM, ADCCP etc). The effect these networks and protocols have on the data path and overall architecture is discussed. Attendees will gain an appreciation for some of the technical challenges such as bandwidth, data buffering, latency and packet loss involved in designing a ground system architecture.

1.2.5 Control Center

This section covers the final processing and handling of the telemetry data before it reaches the operator. The discussion starts with an overview of common black-side functions such as protocol translation and re-serialization to serial-based decryptors. On the red-side, attendees will learn the basics of frame synchronization, decommutation, engineering-unit conversion and Alarms, Warnings and Events (AWE). Applicable standards such as CCSDS telemetry data formats and XTCE are discussed.

1.3 Command Path

After a break, the tutorial focuses on the uplink path by following the commands associated with a specific objective, such as reconditioning the batteries. Since many of the concepts regarding the uplink and network transfers are the same, the main focus is on the aspects unique to satellite commanding.

1.3.1 Control Center

This section starts with the creation of a command sequence targeting a specific objective. On the red-side, attendees learn the main functions of the front-end processors such as command formatting and the common protocols involved (e.g. binary vs ternary). Once the commands have been encrypted, additional formatting such as barker-code insertion is discussed along with technical issues involving time-critical commanding, ground-network interfaces and ensuring consistent command spacing.

1.3.2 Ground Network

A brief overview of the impact the ground network has on commanding is provided with particular focus on time-critical commanding and protocols such as CCSDS SLE. Attendees will gain an appreciation for the differences between uplink and downlink data paths and the affect the ground network may have on performance.

1.3.3 Antenna Site

This section includes a brief overview of the command-specific equipment at the antenna site and command specific functions such as the insertion of fill bits. Topics such as command echo, timed-release.

1.3.4 Space Link

This section highlights differences in the space link between the uplink and the downlink. Attendees will gain an appreciation for the reasons certain types of waveforms are used on the uplink, the asymmetric nature of the communications between the ground and space platforms, and the impact vehicle recovery has on the command bitrates and structures.

1.3.5 Command Verification

The course closes with a brief description of the common on-board command processing and command verification. Attendees will learn the basics of how ground command counts (GCC) and vehicle command counts are used and the application of more advanced topics such as CCSDS COP-1 command processing.

1.4 Industry Trends

This section provides an overview of the trends we are seeing in ground system architecture and provides an open discussion for attendees to share their own experiences.

1.5 Closing Question / Answer Session

Any remaining time is spent in open discussion.

Instructors: Rob Andzik and Randy Culver, AMERGINT Technologies, Inc.

Biographies:
Rob Andzik's Bio: I love working in the space industry. I graduated from CU with a BS in Aerospace Engineering and Computer Science. Previous experience at Lockheed Martin and RT Logic. I am co-chair of the OMG Space Domain Task Force and co-author of the Ground Equipment Monitoring Service (GEMS) specification. Fun Fact: I enjoy spending time with my family and riding my mountain bike. I also work with a small relief organization in Kenya and Ethiopia called Lalmba.

Randy Culver's Bio: I enjoy working with our customers to understand what they need to implement their systems. Systems Architect/Manager for 25+ years. MSEE – Purdue, BS – VA Tech. Prior Experience at IBM and RT Logic. Fun Fact: I competed on Team USA at the World Duathlon Championships in Spain.

Description of Intended Students and Prerequisites:
Course is of interest to systems engineers, architects, and operators who require a basic understanding of satellite communications links and the implementation of the ground system to receive/transmit and transport the telemetry and command data.

Attendees should have a basic understanding of satellite operations, and preferably an engineering background.

What can Attendees Expect to Learn:
Attendees will leave with a general understanding of satellite communications between space and ground, over ground networks, and within a control center. The course reviews common implementations for telemetry, commanding, ranging, and mission links.