GSAW 2022 Tutorial H:

Introduction To Satellite Communications

Overview:
1 Telemetry & Command Course Outline
This 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.

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.
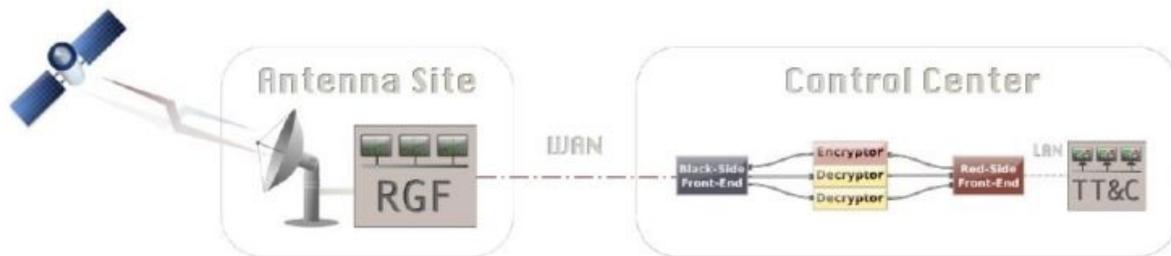
1.2 TELEMETRY PATH
The main part of the tutorial begins by following a satellite telemetry point (e.g. battery voltage) from the spacecraft to the operator on the ground.1.2.1 Onboard The Spacecraft
This section includes a brief discussion of how the telemetry is commonly assembled, what data formats (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 encryption processing. 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 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. In particular, 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. Also an overview of Cloud-Based processing and how to design a virtual ground system using platforms such as AWS Ground Space Marketplace.

1.5 CLOSING QUESTION / ANSWER SESSION
Any remaining time is spent in open discussion.

Instructor:
Brian Willette, AMERGINT Technologies Inc.

Biography:
Brian Willette is the Vice President of Project Management And Operations at AMERGINT Technologies and manages the infrastructure and execution of AMERGINT's portfolio. Brian has over 15 years of space domain experience, and over 25 years of working in the software product development industry, including multiple small internet startups, as well as his time working in the research and development labs. Brian holds a patent, has been published, and sits in the Engineering Leadership Council for the University of Colorado at Colorado Springs, where he graduated with his bachelor's degree in Computer Science in 1995, and will graduate with an MBA in finance in 2022.

Description of Intended Students and Prerequisites:
Attendees should have a basic understanding of satellite operations and an engineering background.

What can Attendees Expect to Learn:
Attendees will learn how satellite communications work from the satellite to the operator. This includes an overview of the RF link as well as common telemetry, command and other data formats used in satellite link.