Autonomous Flight Termination System (AFTS)

Customer: NASA, Department of Defense (DoD), Commercial

Goal: Enable low cost, responsive, reliable access to space

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What is AFTS?

- **Concept of Autonomous Flight Termination System (AFTS)**
  - **Box on the vehicle - Autonomous Flight Termination Unit (AFTU)**
    - Tracking from Global Positioning System (GPS) and Inertial Navigation System (INS) sensors
    - Rule set built in pre-flight period
    - If a rule is violated the flight is terminated
  - **Radar and Command stations recede into past**
  - **Telemetry down-link drops from safety critical to sit awareness, post-flight, & mishap**
- **Some jobs stay with the humans**
  - **Clear to launch**
    - Good AFTU load
    - Clear range
    - Weather constraints
  - **Mishap announcement and investigation**
    - Air traffic
    - Sea and Ground Debris
  - **Post-flight data review**

Project: Autonomous Flight Termination System (AFTS)

- Definition
  - The Autonomous Flight Termination System (AFTS) is an independent, self-contained subsystem mounted onboard a launch vehicle
  - AFTS flight software has been developed by and is owned by the US Government
  - AFTS autonomously makes flight termination / destruct decisions using configurable software-based rules implemented on redundant flight processors using data from redundant GPS/Inertial Measurement Unit (IMU) navigation sensors
- Applications
  - Primary Flight Termination System (FTS) for unmanned Range Safety Operations
  - Primary FTS or Crew advisory system for human space flight
- Advantages
  - Cost reduction due to decreased need for ground-based assets
  - Global coverage (vehicle does not have to be launched from a range)
  - Increased launch responsiveness
  - Boundary limits increase due to 3-5 second gain from not having Mission Flight Control Officer (MFCO).
  - Can support multiple vehicles simultaneously (such as fly-back boosters)

Traditional FTS

Flight Systems

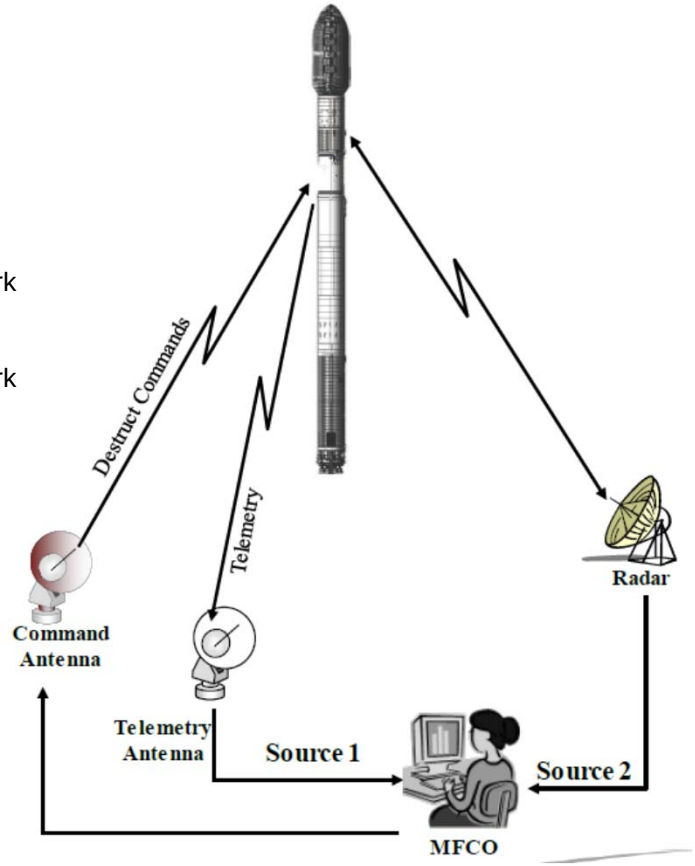
- Flight Termination System
  - Receiver
  - FTS Logic Box
  - Battery
  - UHF Antenna
  - Hybrid Coupler
  - Safe & Arm
  - Ordnance
- Metric Tracking Sources (Range Commander's Console (RCC) 324)
  - GPS
  - Telemetry Encoder
  - Telemetry Transmitter
  - S-band Antenna
  - L-band Antenna
  - Couplers
  - Power Distribution Box
  - Vehicle Battery
- Radar Transponder
  - Transponder
  - C-band Antenna
  - Hybrid Coupler
  - Power Distribution Box
  - Vehicle Battery

Ground Systems

- Command Transmitters
  - Power Supplies (Redundant Sources)
  - Antennas (Omnis & Directional)
  - Amplifiers (10 kW Tubes)
- Telemetry Receivers
  - Antennas
  - Decoders
  - Ground Communications Network
- Radars
  - Radar Sites
  - Ground Communications Network
  - Timing Infrastructure
- Mission Flight Control
  - MFCO
  - Telemetry Officer
  - Certified Displays

Operational Considerations

- Telemetry Formats
- Telemetry Tapes
- Launch Constraints
- Range assets are degrading and/or being decommissioned



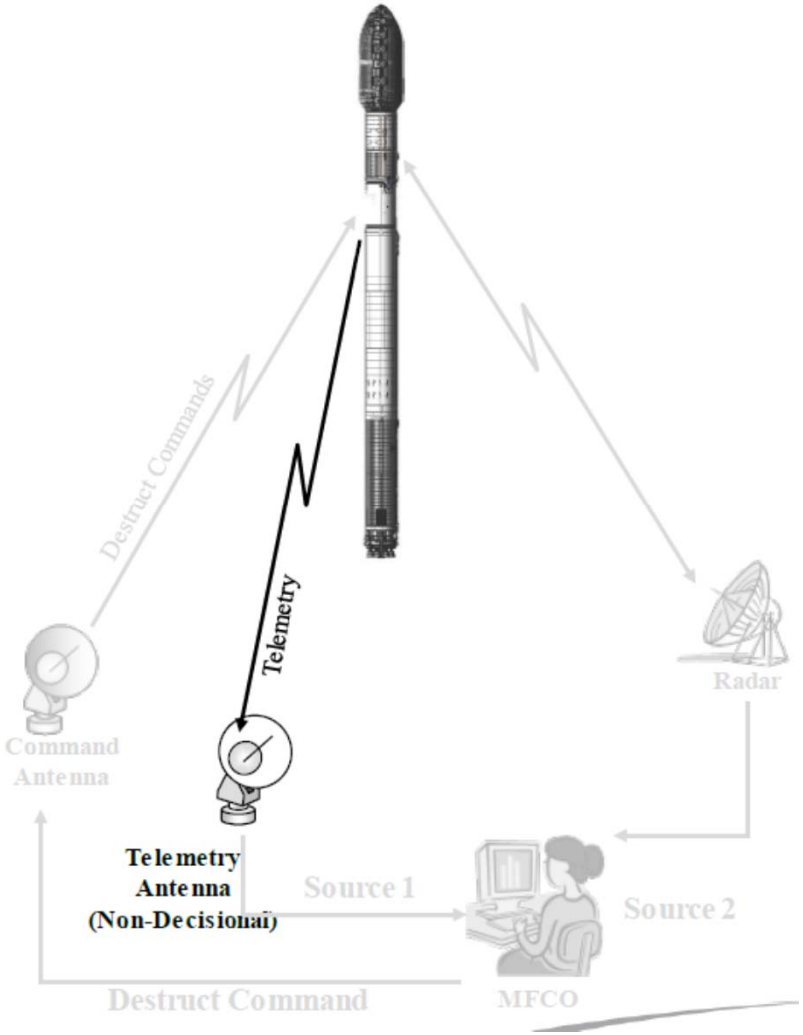
Autonomous FTS

Flight Systems

– Metric Tracking Sources (RCC 324)
  - GPS (x3)
  - L-band Antennas
  - Coupler
  - IMU/INS
  - Flight Computer
  - Power Distribution Box
  - Vehicle Battery
– Flight Termination System
  - Autonomous Flight Termination Unit
  - Safe & Arm
  - Thrust termination/Ordnance

Other

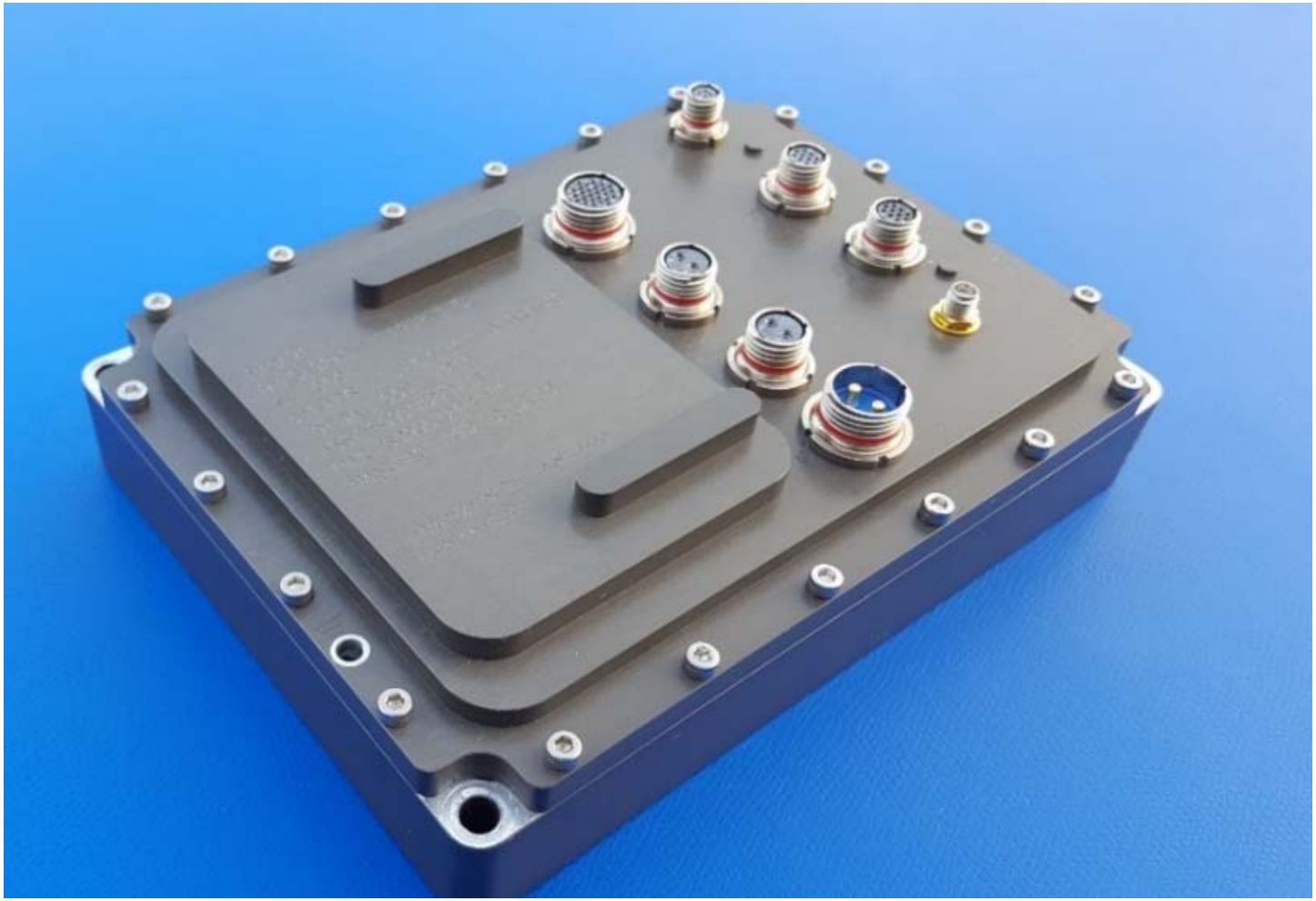
– Preflight Testing



NASA and DoD AFTS Development Team

- NASA has maintained a multi-center AFTS engineering development team since 2000, responsible for technology development
- The partnership with the DoD began in 2002 under the joint NASA/United States Air Force (USAF) Advanced Range Technologies Working Group
- The Goal of NASA and DoD has always been to develop an AFTS system that is available for use by all Range Users within International Traffic in Arms Regulations (ITAR) that can greatly reduce the cost of access to space
- AFTS has been supported by several NASA and DoD programs since its inception.
- AFTS recently won the Federal Labs Consortium National Interagency Partnership Award
- The AFTS design package has been transferred to 36 U.S. Companies and U.S. Federal Agencies to date

AFTS Engineering Flight Hardware



AFTS Overview

AFTU Overview

- <3 lbs.
- Nominally <7 watts at 28 V DC
- Estimate 7.5” X 5.5” X 2”
- Outputs discrete signals or up to 5.5 amps at 28 V DC
- Term or TermNOT (for normally closed valves) configurable
- Using Mil-spec parts (simplified piece parts plan) in critical circuits
- Qualifying to Air Force(AF)/NASA/Federal Aviation Administration(FAA) range requirements.
- Up to 5 sensor combinations may be connected to one AFTU
    - GPS, INS, GPS/INS hybrid or IMU.
- Single or cross strapped configurations.

Key Requirements

- No single point failure (failsafe exception for single AFTU)
- Ensure no inadvertent termination
- 0.999 Reliable at 95% Confidence.
- Range Commander’s Console (RCC) 319-14
- RCC 324-11
- 91-710 Vol 4 Attachment 3
- 91-712
- CASS Requirement Spec

AFTS Flight Demonstrations with current hardware/software

Four Rocket Lab Electron launches to date with AFTS in shadow mode with one additional shadow flight before AFTS is used operationally (scheduled for early August 2019)

One UP Aerospace SL-12 launch to date with AFTS in shadow mode with one additional shadow flight on SL-14 before AFTS is used operationally on UP Spyder (scheduled for 2020)