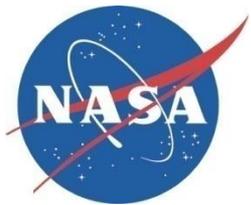




# Autonomous Flight Termination System (AFTS)

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ICG-14 WG-B  
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# AFTS

## Concept of Autonomous Flight Termination System

- **Box on the vehicle (AFTU)**
  - Tracking from GPS and 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**
- **Post-flight data review**

## Status:

- **After hardware qualification, software certification, and 8 shadow flights, the NASA AFTU flew operationally on Rocket Lab Electron on Friday, Dec 6, 2019**





# Traditional FTS

## Flight Systems

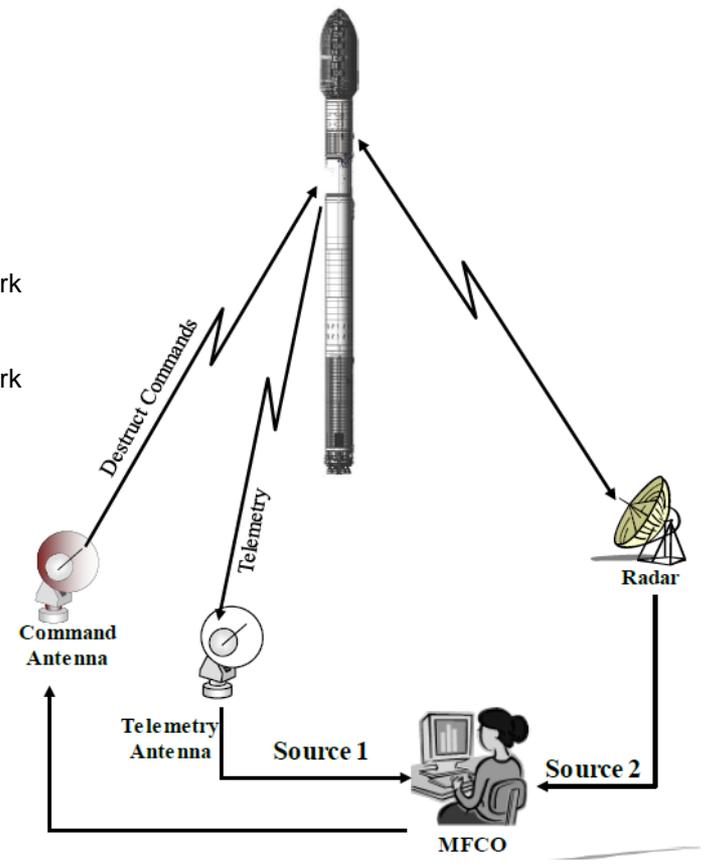
- Flight Termination System
  - Receiver
  - FTS Logic Box
  - Battery
  - UHF Antenna
  - Hybrid Coupler
  - Safe & Arm
  - Ordnance
- Metric Tracking Sources (RCC 324)
  - GPS
  - Telemetry Encoder
  - Telemetry Transmitter
  - S-band Antenna
  - L-band Antenna
  - Couplers
  - Power Distribution Box
  - 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





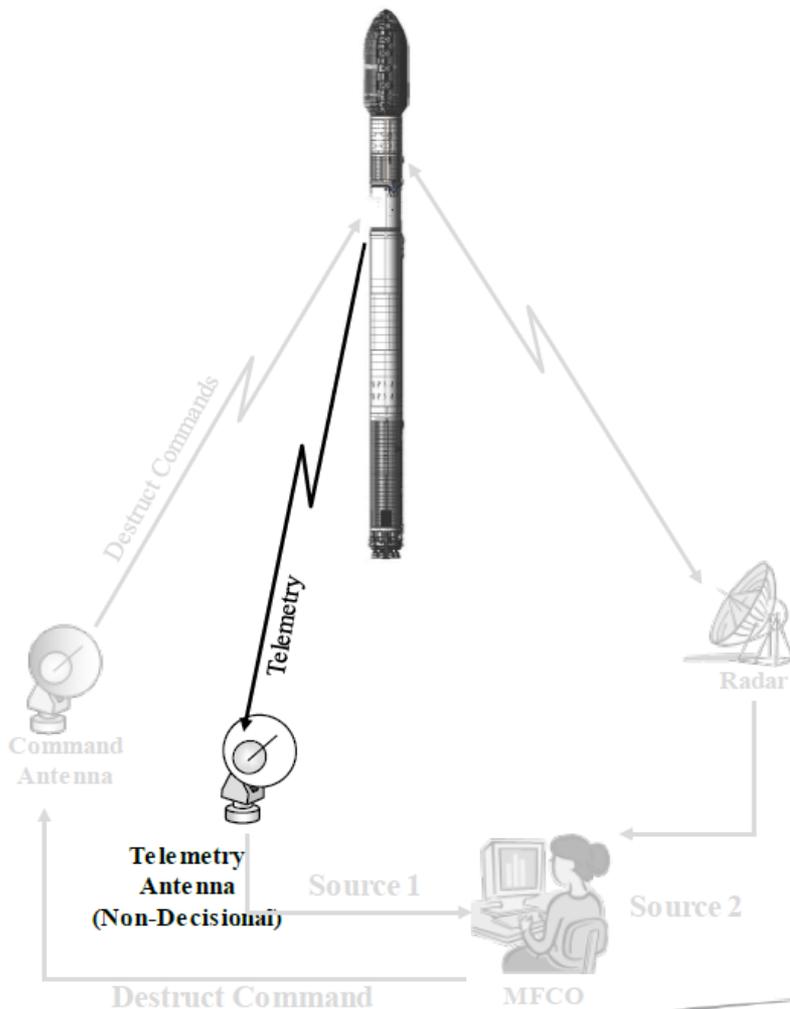
# Autonomous FTS

## Flight Systems

- Metric Tracking Sources (RCC 324)
  - GPS
  - 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





# ***Project: Autonomous Flight Termination System (AFTS)***

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- Definition
  - The Autonomous Flight Termination System (AFTS) is an independent, self-contained subsystem mounted onboard a launch vehicle
  - AFTS autonomously makes flight termination / destruct decisions using configurable software-based rules implemented on redundant flight processors using data from redundant GPS/IMU navigation sensors
- Applications
  - Primary 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 MFCO
  - Can support multiple vehicles simultaneously (such as flyback boosters)



# ***AFTS Launch Demonstrations to mature flight software***

## **Flight/Launch Demos:**

- Sept. 27, 2005, aircraft flight test near Kennedy Space Center
- Apr. 5, 2006, Two-stage Terrier Orion Sounding Rocket at WSMR
- Mar. 21, 2007, SpaceX Falcon 1 at Reagan Test Site, Kwajalein
- Nov. 8, 2007, F-104 aircraft at Kennedy Space Center SLF
- Sept. 21, 2010, Two-stage Terrier Orion Sounding Rocket at WFF
- Nov. 19, 2013, DoD ORS demonstrated ATK AFTS on Minotaur from WFF



**F-104**



**Sounding Rocket at WSMR**



**SpaceX Launch**



**Sounding Rocket at WFF**



# ***Project: AFTS Technical Progress***

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## **CASS Software**

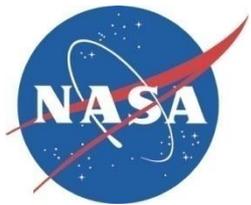
- NASA wrote the original AFTS Core Autonomous Safety Software (CASS) algorithms and software
- The USAF Air Force (30<sup>th</sup> Space Wing) rewrote CASS to make it safety critical for operational use, and distributes CASS to users via SUA within ITAR
- KSC performed testing, IV&V and AFTS project management
- An AFTS using CASS Operational Release 1.1 (OR 1.1) was flown operationally for the first time by a launch vehicle provider on February 19, 2017 with many other companies to follow.
- All launch vehicle providers plan to use CASS in their AFTS, even though their AFTS hardware and wrapper software may vary from company to company

## **WRAPPER Software**

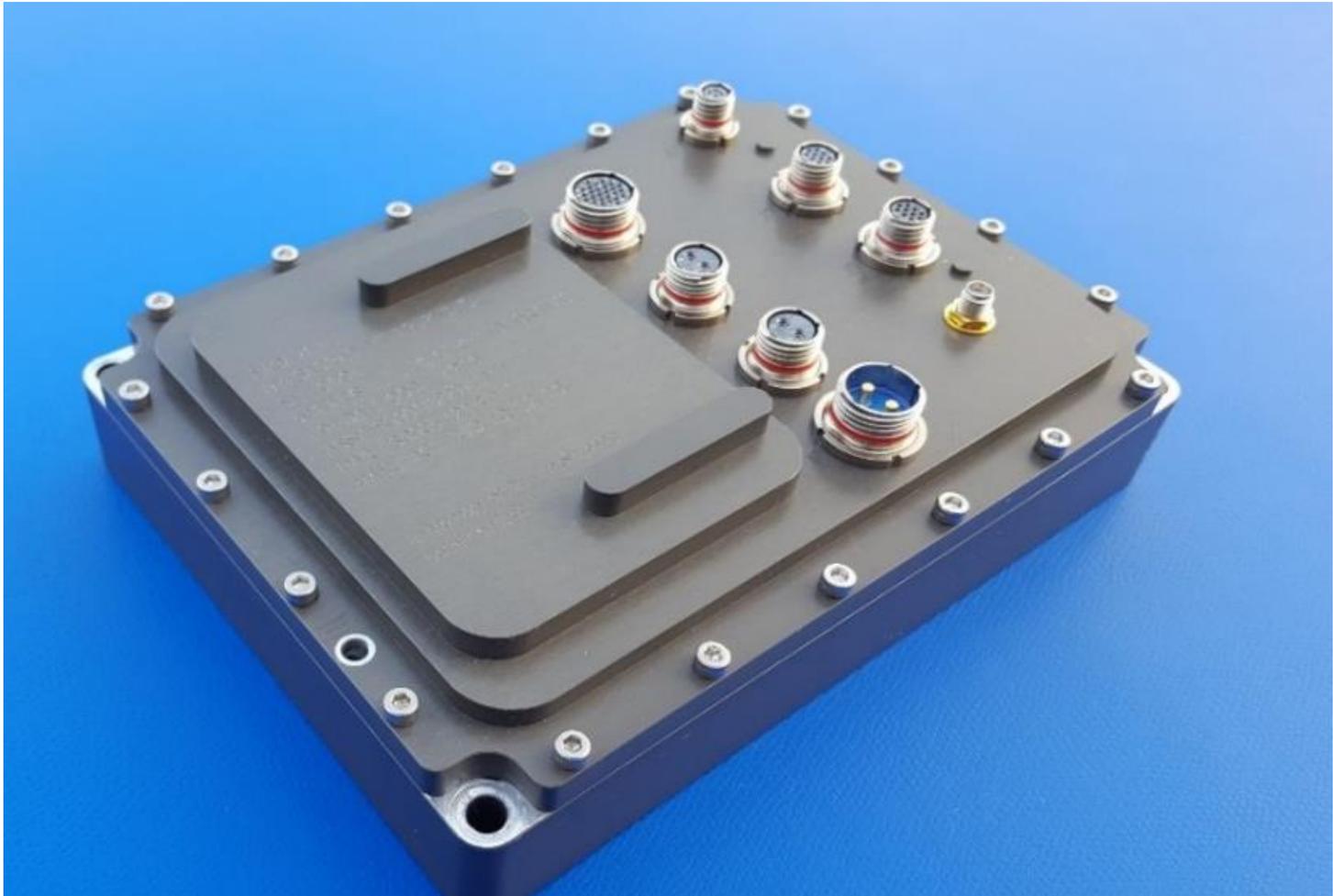
- The Wrapper software is necessary to interface between CASS and AFTS hardware
- NASA KSC has released Wrapper software via free technology transfer to Range Users within ITAR

## **AFTS Hardware Development**

- One launch vehicle provider has developed, certified, and qualified their proprietary AFTS hardware, along with their custom Wrapper software, for operations on the Eastern and Western Ranges
- KSC has designed a generic AFTS hardware architecture that can be used as a reference by future Range Users wanting to implement an AFTS on their launch vehicle – the commercialization office at KSC has released the NASA hardware design via free technology transfer to Range Users within ITAR



# *AFTS Engineering Flight Hardware*





# AFTS Overview

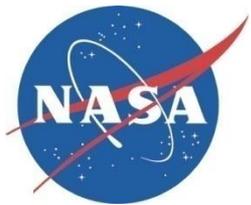
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## AFTU Overview

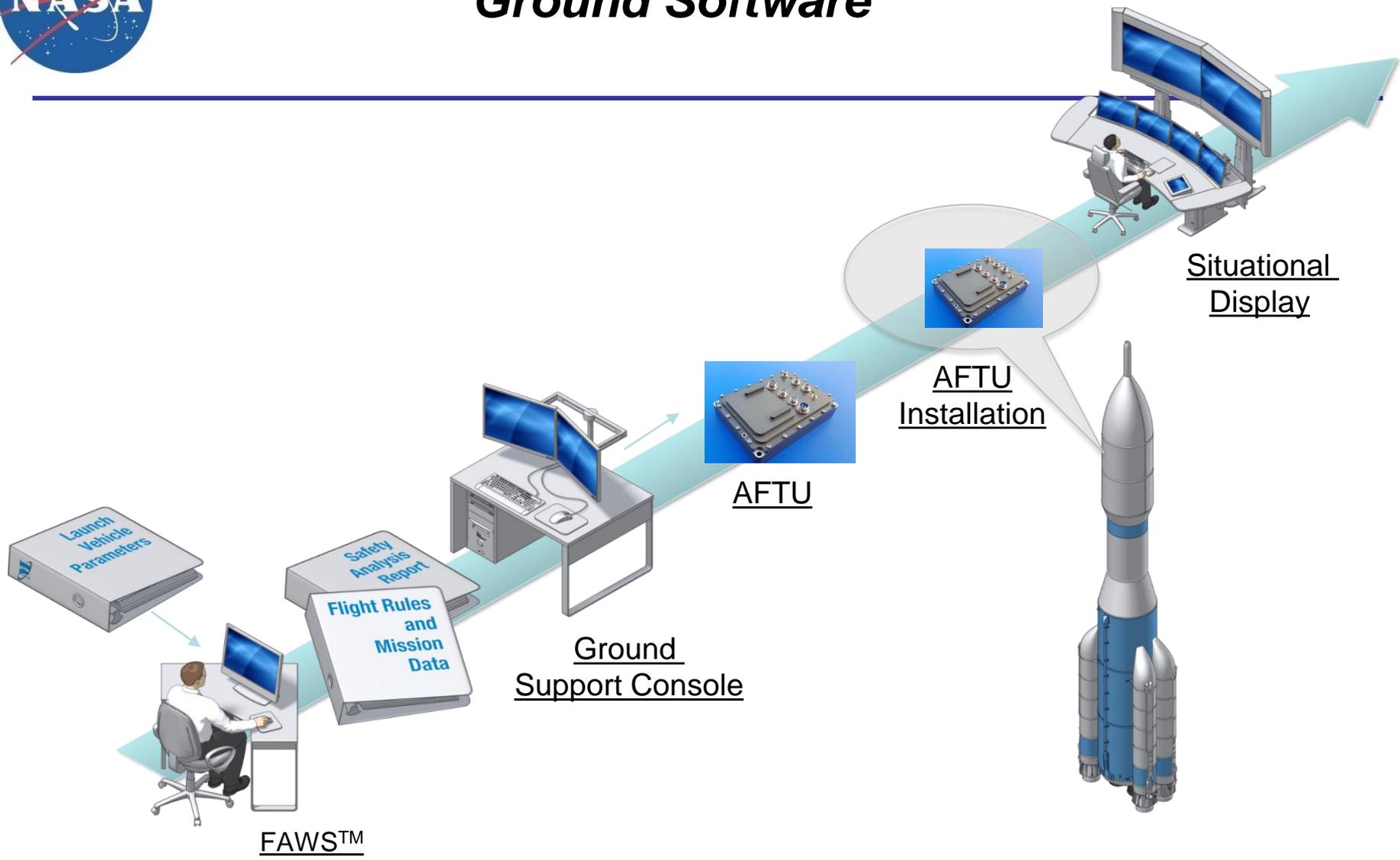
- < 1.3kg
- Nominally <7 watts at 28 V DC
- Estimate 5cm X 14cm X 19cm
- Outputs discrete signals or up to 5.5 amps at 28 V DC
- Term or TermNOT (for normally closed valves) configurable
- Using Mil-spec parts (simplified piece parts plan) in critical circuits
- Qualifying to AF/NASA/FAA range requirements.
- **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.
- RCC 319-14
- RCC 324-11
- 91-712
- CASS Requirement Spec



# Ground Software

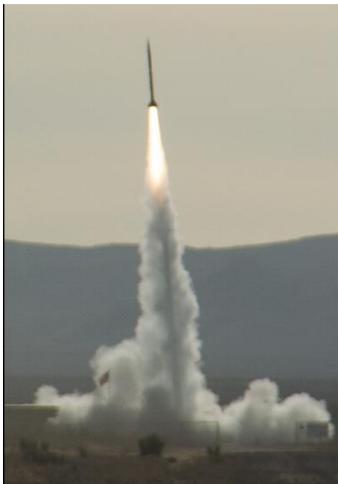




## ***NASA AFTU Flight Tests***

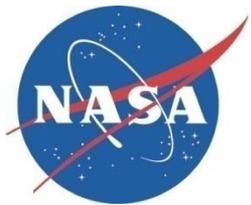


**Rocket Lab Electron Launch**

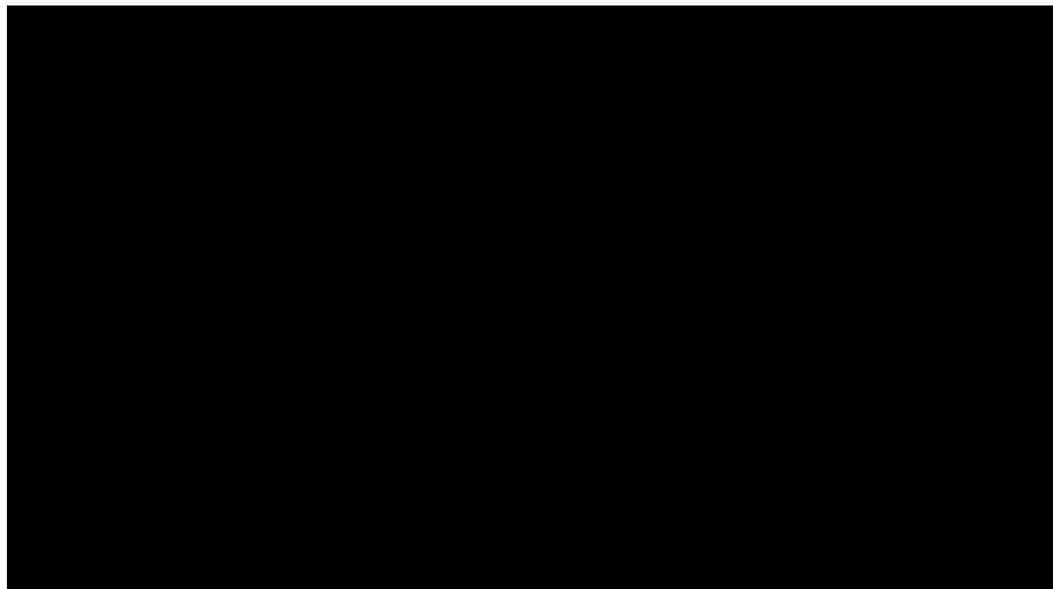


**UP Aerospace Spaceloft Launch**

- DARPA initiated a partnership with NASA on a low cost, flight demo to flight test KSC's AFTS Reference Design Hardware
- The ride share demonstrated the AFTS system (with validated CASS SW).
- This demonstrated a path forward that doesn't require traditional Range support for vehicle tracking and command destruct.
- The DARPA funded, NASA AFTS payload launched on Rocket Lab's Electron Launch Vehicle from New Zealand in 5/2017.
- DARPA has selected three additional RL flights to fly two of their AFTS units on each as shadow/certification flights.
  - All three certification flights have been completed
- NASA AFRC purchased 6 units; two flown on UP Aerospace SL-12 launch, on a bonus RL launch, two (from SL-12) re-flown on UP Aerospace SL-14, two to NASA WFF for testing. WFF flew one on a sounding rocket in Oct 2019.
- The first launch using the DARPA/NASA AFTU for primary operations occurred on Friday, Dec 6, 2019.
- Several launch vehicles have baselined the NASA AFTS units into their vehicles for operational use in the future.



# Rocket Lab Electron Launch NASA AFTS First Operational Flight



<https://youtu.be/bTyIS5aJSGI?t=1535>

