LEO to GEO Communications from Concept to On Orbit Mission Success

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National Aeronautics and Space Administration

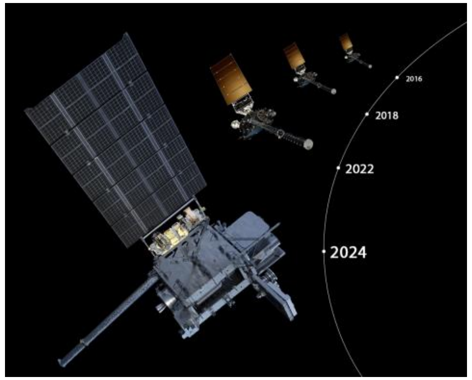
Ames Research Center

Logo: **Stanley Krześniak**

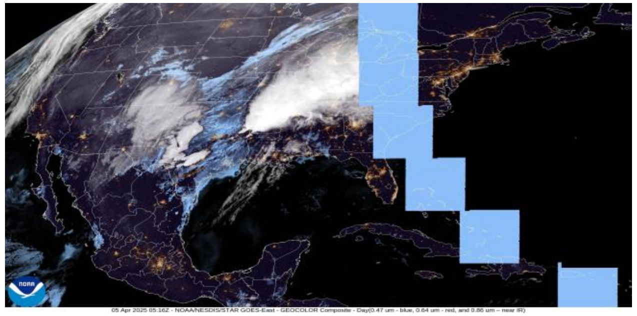
NOAA GOES and DCS system

GOES Satellite Constellation

- Geostationary Operational Environmental Satellites (GOES) operational since 1975
- GOES 18 (West)-19 (East) are currently operational. 19 was just put into service
- Supply multispectral images and other weather/climate data
- GOES is essential for weather forecasting, climate studies, shipping, and emergency management



NOAA GOES Satellite
Image courtesy of NASA Science



GOES Satellite Image
Image Courtesy of NOAA

DCS System

- Data Collection System(DCS) Implemented with the first GOES constellation in 1975
- Provides access to multiple users at 300 and 1200 bps
- Uses UHF (402-403) Mhz. Channelized and table driven
- Data is downlinked from GOES to Wallops Island in L band and distributed via the internet
- There are currently about 3000 users

Channel number	Frequency (MHz)	Channel number	Frequency (MHz)	Channel number	Frequency (MHz)	Channel number	Frequency (MHz)
1	401.701000	312	401.718250	**24**	**401.735500**	335	401.752750
301	**401.701750**	13	401.719000	324	401.736250	**36**	**401.753500**
2	401.702500	**313**	**401.719750**	25	401.737000	336	401.754250
302	401.703250	14	401.720500	**325**	**401.737750**	37	401.755000
3	**401.704000**	314	401.721250	26	401.738500	**337**	**401.755750**
303	401.704750	**15**	**401.722000**	326	401.739250	38	401.756500
4	401.705500	315	401.722750	**27**	**401.740000**	338	401.757250
304	**401.706250**	16	401.723500	327	401.740750	**39**	**401.758000**
5	401.707000	**316**	**401.724250**	28	401.741500	339	401.758750
305	401.707750	17	401.725000	**328**	**401.742250**	40	401.759500
6	**401.708500**	317	401.725750	29	401.743000	**340**	**401.760250**
306	401.709250	**18**	**401.726500**	329	401.743750	41	401.761000
7	401.710000	318	401.727250	**30**	**401.744500**	341	401.761750
307	**401.710750**	19	401.728000	330	401.745250	**42**	**401.762500**
8	401.711500	**319**	**401.728750**	31	401.746000	342	401.763250
308	401.712250	20	401.729500	**331**	**401.746750**	43	401.764000
9	**401.713000**	320	401.730250	32	401.747500	**343**	**401.764750**
309	401.713750	**21**	**401.731000**	332	401.748250	44	401.765500
10	401.714500	321	401.731750	**33**	**401.749000**	344	401.766250
310	**401.715250**	22	401.732500	333	401.749750	**45**	**401.767000**
11	401.716000	**322**	**401.733250**	34	401.750500	345	401.767750
311	401.716750	23	401.734000	**334**	**401.751250**	46	401.768500
12	**401.717500**	323	401.734750	35	401.752000	**346**	**401.769250**

GOES V 2.0 DCS frequencies for channels 1 through 46 and 301 through 346

NOAA LEO DCS Project

Objectives

- Collaboration between NASA Ames, NOAA, and Microcom, and Aerospace Corp to integrate GOES DCS hardware into a TechEdSat bus to prove the system could provide connectivity from LEO to GEO to ground
- Connect via GOES-E or GOES-W or International partners
- Test methods for dealing with Doppler compensation and operating between multiple GEO satellites

NASA Interests

- LEO to GEO communication methods: what works
- DCS uses frequencies proposed for Mars communications so what is learned can be applied
- The GOES constellation is reachable from the Lunar surface

NOAA Interests

- New use of DCS and provide space-based sensors for
  - Ocean and atmospheric monitoring
  - Detection of forest fires, earthquakes solar storms, and other hazards requiring immediate attention

Image courtesy of NOAA/NASA

Image courtesy of MicroCom

Image courtesy of NOAA

Technology Education Satellite (TechEdSat) Flight Series

The team consists of the TES-n Rapid Flight Development group at NASA Ames, located within the Engineering Directorate. Consisting of several experienced individuals, mid-career, early-career, and interns, it has successfully launched and operated 13 nano-sats. As of March 2025, the group is operating 2 nano-sats and is building the next set of nano-sats. The team produced the first NASA CubeSat deployed from the ISS (then first 3U, long 6U). The team also collaborates with several universities to develop flight tests of Experiments, Sensors, and Subsystems.

Current team members include:

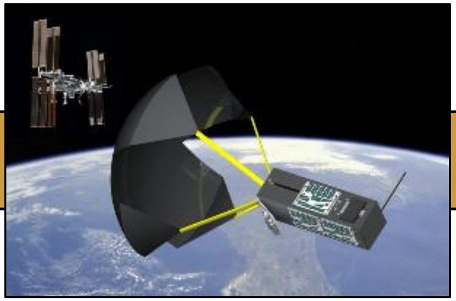
Key Collaborators: K. Ling/ARC, J. Briones/GRC, L. Schisler/KSC, O. Hatamleh/ARC, M. Campola/GSFC, E. Barszcz/ARC, M. Rudolph/ExpInst, T. Taha/UofDayton, P. Papadopoulos/SJSU, M. Lowry/ARC, A. Gillete/ARC, N. McDonald/AFRL

Core TES-n Team: M. Murbach/*PI, PM*, A. Dave/*DPM*; J. Alvarellos/*Flight Dynamics*; T. Hector/ *S&MA*; A. Salas/*Lead CS*; M. Mooney-Rivkin/*Lead ME*; A. Brock/*Lead EE*; K. Boateng/*Lead SE; T. Stone/Principal Engineer*

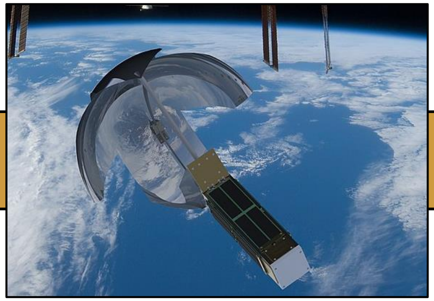
Universities: San Jose State University, University of Minnesota, University of Idaho, University California/Davis, University of California/Santa Cruz, University of Dayton

Reporting/Reviews: All TES-n spacecraft are formulated as NPR7120.8 projects. Each spacecraft undergo design reviews (PDR, CDR, FRR) with the Ames Chief Engineer. The team reports monthly on progress to the Ames Spacecraft Projects Office (SPO).

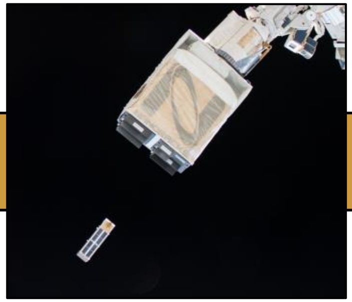
TES Mission History (2015-2025)



TES-4 (2015)

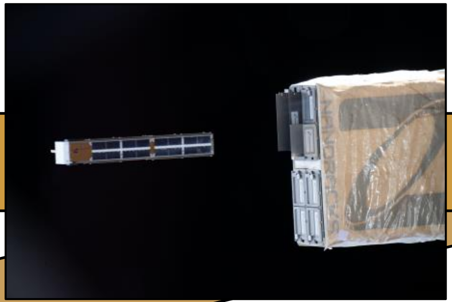


TES-5 (2016)

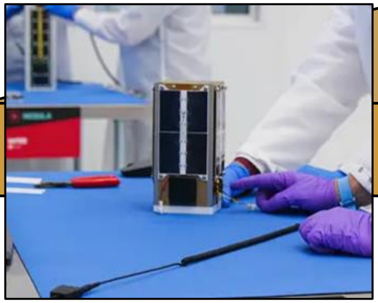


TES-6 (2017)

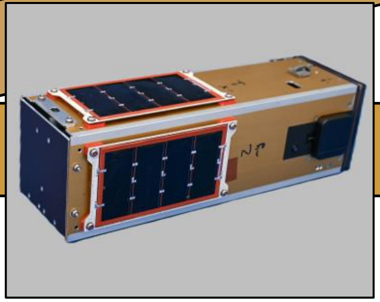
TES-8 (2018)



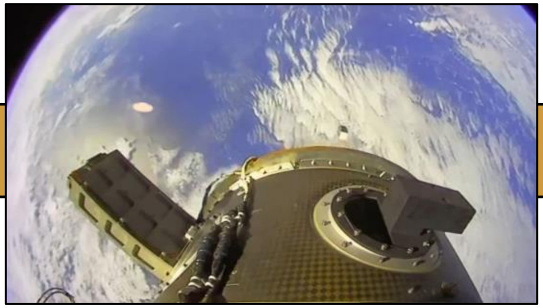
TES-10 (2020)



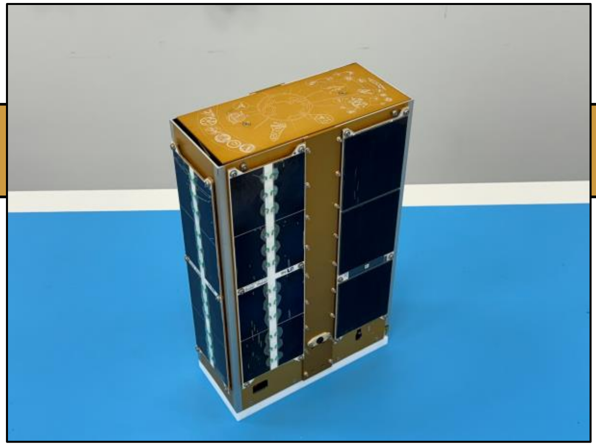
TES-7 (2021)



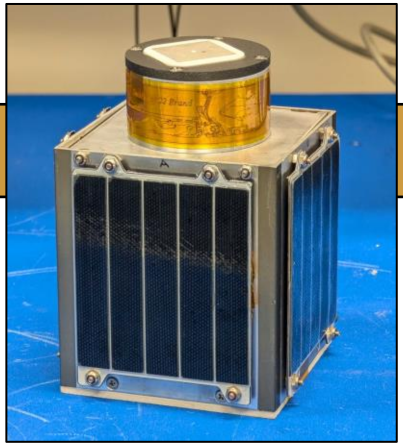
TES-13 (2022)



TES-15 (2022)



TES-11 (2024)



TES-22 (2025)

Images courtesy of NASA

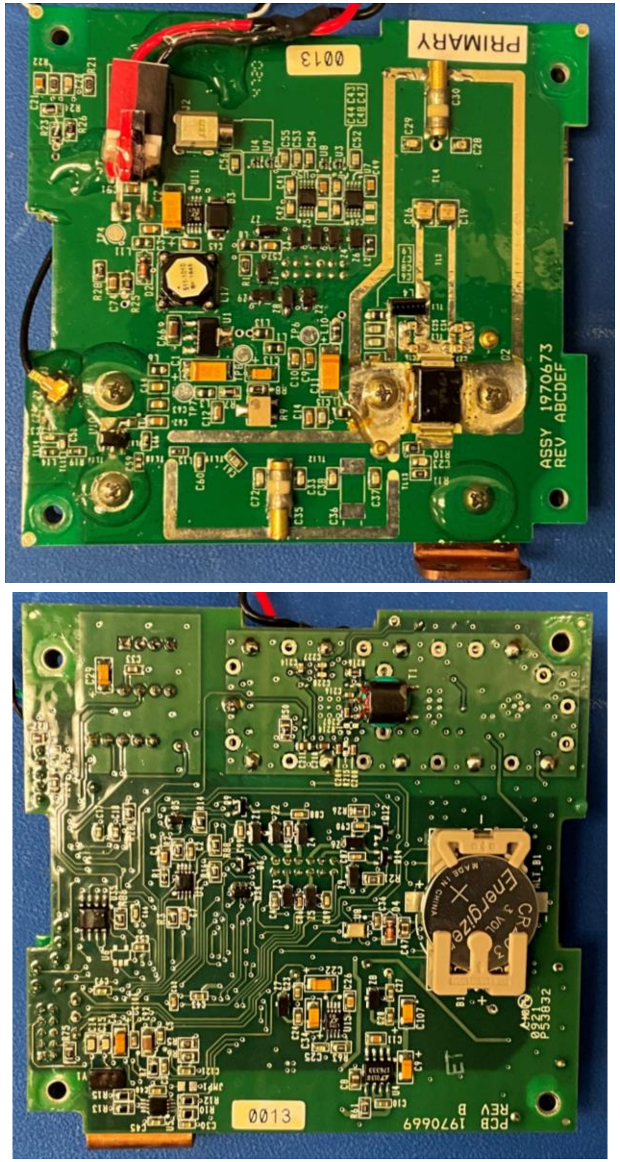
GOES DCS Radio GTX-2.0SS

Custom radio was designed to fit into the TechEdSat Stack

- Designed by Microcom, a company who helped design the DCS standard and develops ground units for many DCS users
- Adapted the ground standard ground radio units to comply the PC/104 standard and operate on the 8V bus voltage

GTX 2.0 Ground Unit
Image courtesy of MicroCom

NOAA DCS Radio



Specifications

- Power: 45W Electrical, 10W RF max
- Frequency: UHF (401-403 MHz)
- Bandwidth: 100, 300, and 1200 bps
- Utilizes an omnidirectional Whip Antenna

Images courtesy of NASA

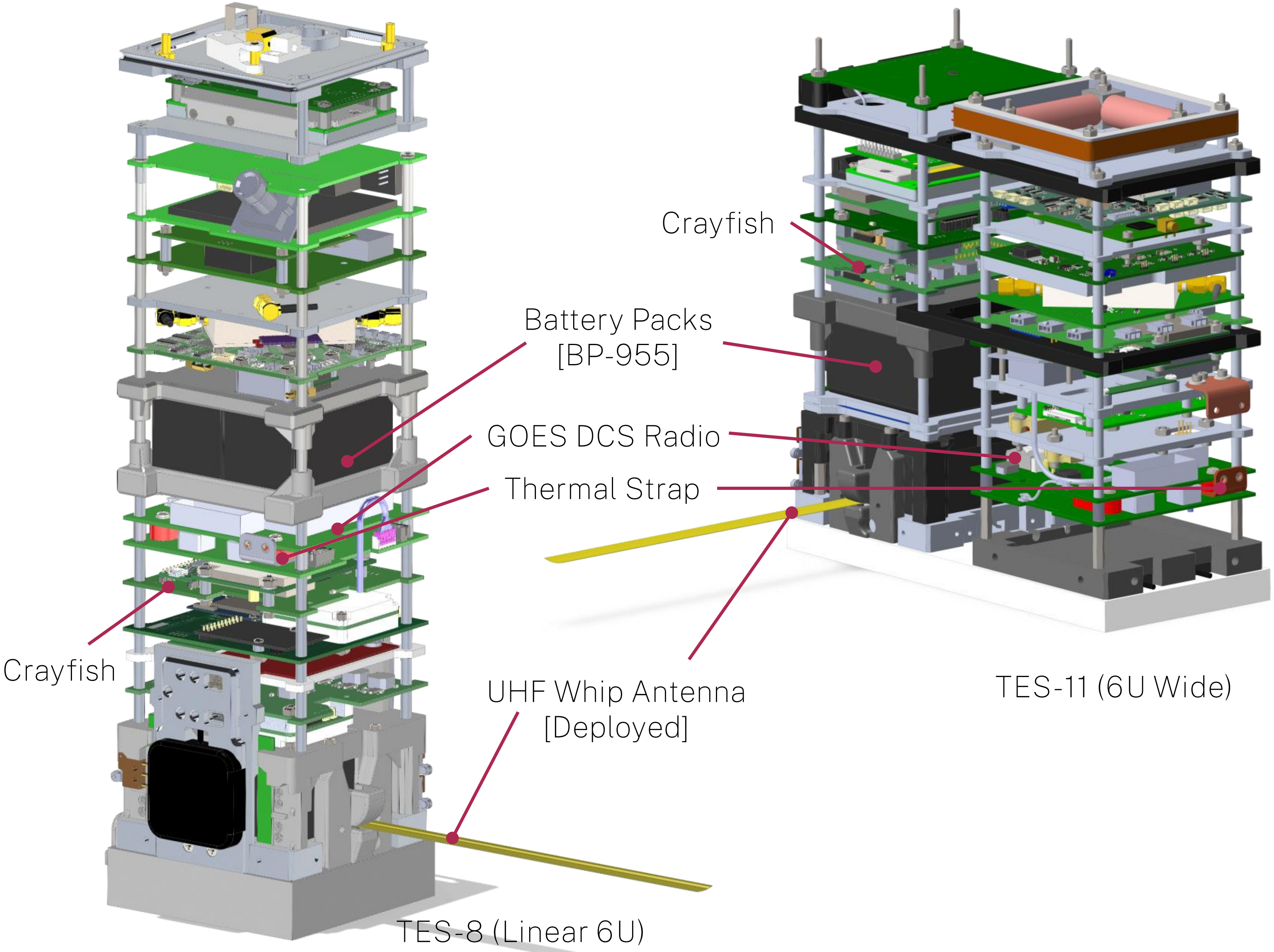
Payload Integration

Challenges

- The TES bus was modified to provide the power, thermal, and data requirements of the radio
  - A new thermal strap was used to reject heat, the battery capacity was doubled, and gps data was fed directly to the radio

Subsystem Components

- Crayfish: acts as the interface between the radio and bus
- DCS Radio and Whip Antenna: the primary payload
- BP-955 Batteries: provide 150 Wh of energy and the 45W of power for transmissions



Images courtesy of NASA

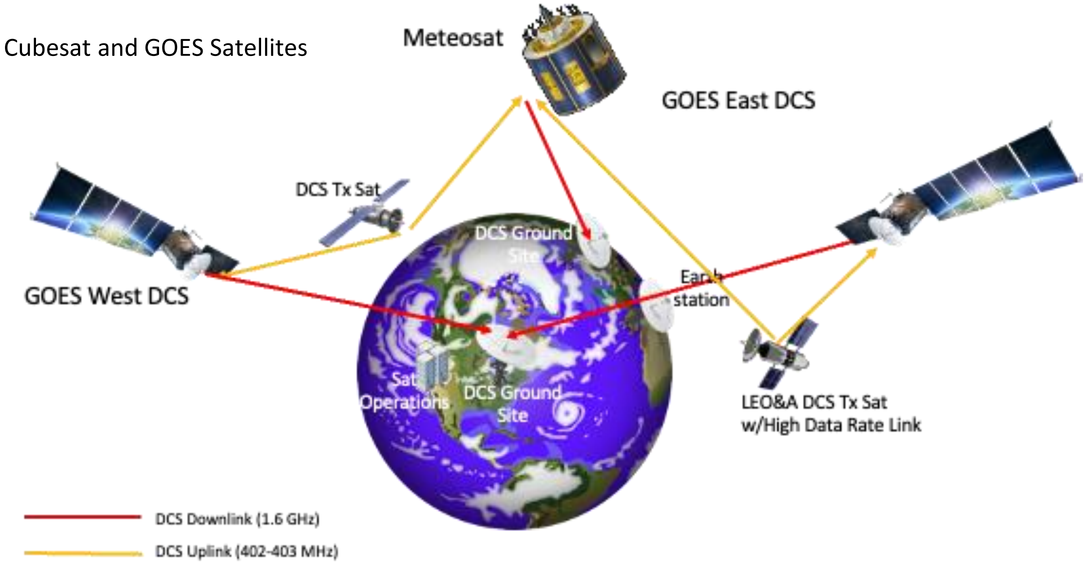
Concept of Operation

Doppler Correction

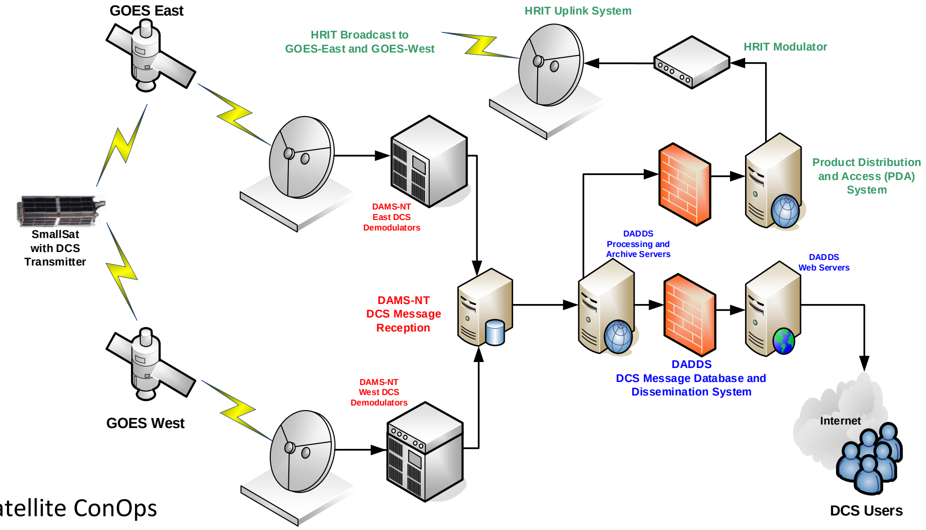
- Doppler compensation is required depending on the location of the spacecraft in relation to the GOES satellite
- The code to determine doppler correction was developed by David Kunkee (Aerospace Inc.) with help from ARC
- The offset is sent to the Microcom board with the packet to be transmitted

CONOPS

- Transmission commands with doppler correction and transmit times are sent to the radio
- The radio transmits at either 100, 300, or 1200 bps at the scheduled transmission time to either GOES East or West
- GOES forwards to the Ground Station at Wallops
- Wallops logs transmission into the DCS databaseto be viewed by the user over the internet



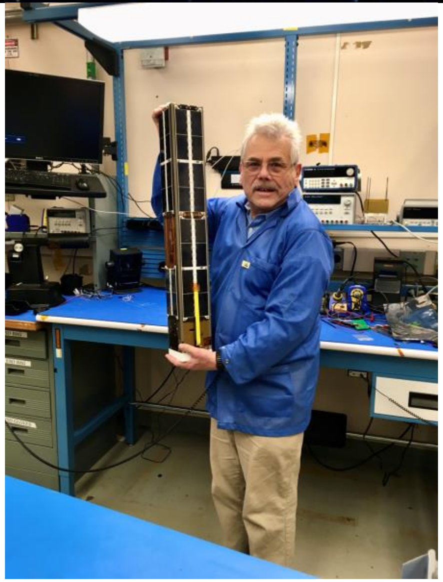
Cubesat and GOES Satellites

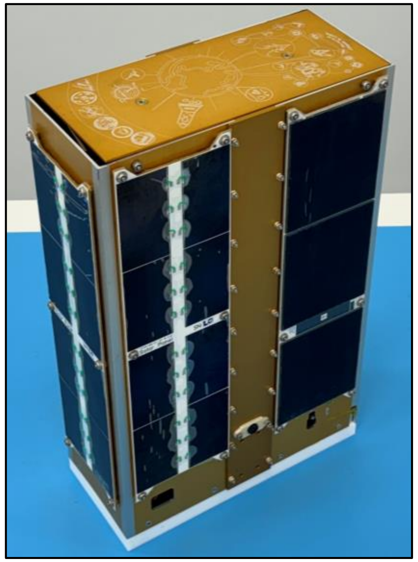


Satellite ConOps

Images courtesy of NOAA/Aerospace

Flight History





TES-8

- First test flight of the DCS Radio
- Radio turned on and pinged, but data was transmitted

TES-10

- Re-flight of TES-8 DCS hardware
- transmitted successfully to both GOES-E, and GOES-W with minimal packet loss at 300 bps and 10W

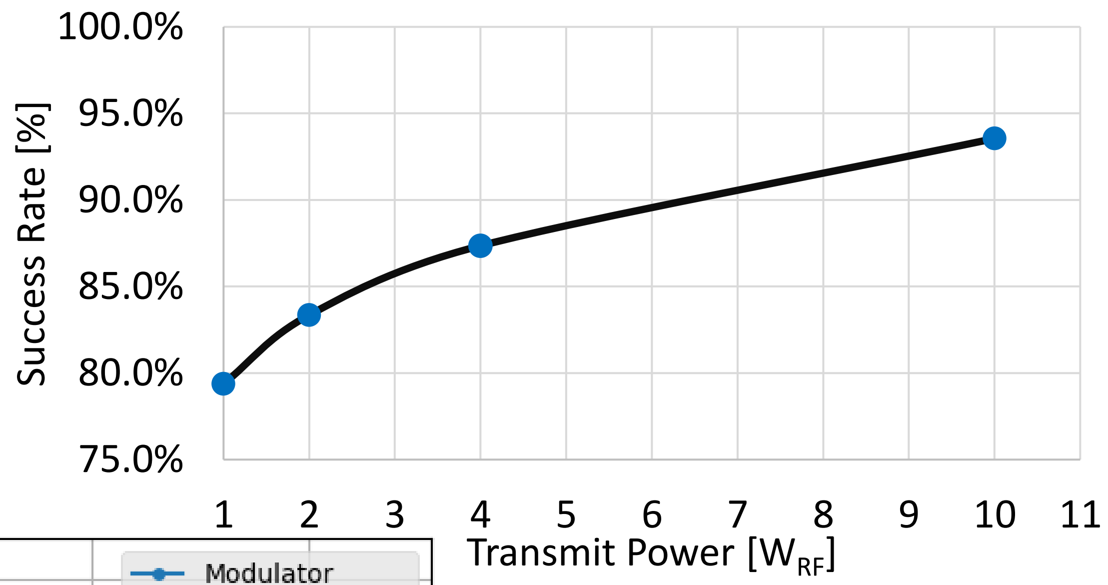
TES-11

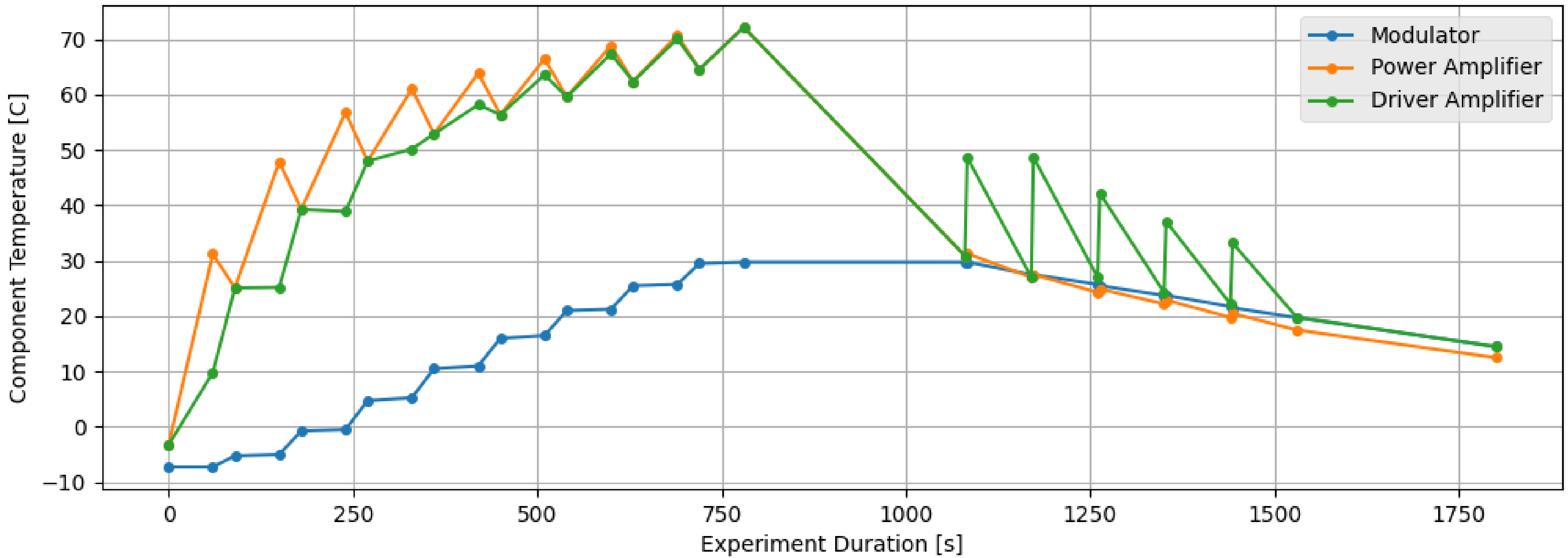
- Upgraded DCS hardware with real time clock and back up battery
- Successfully transmitted to GOES-E and GOES-W at 300, and 1200 bps at 0.5-10W RF
- Successfully transmitted to Eumetsat at 1200 bps at .5-10W RF

The GOES DCS radio has flown onTES-8, TES-10, and TES-11 missions and required a 6U bus to provide a stable power system
Successfully proved that TES-DCS is a success and could be made operational

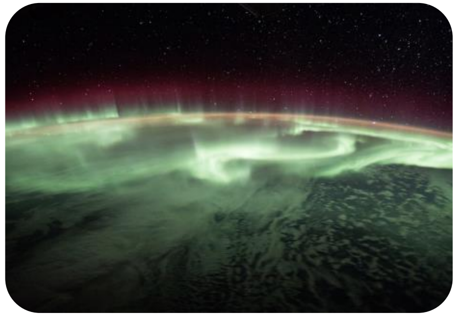
Flight Results

- Although downlink only the GOES link was just as reliable than our primary Iridium connection
- the power required to complete the link was less than expected, a link could be completed at 0.5W
- The doppler correction algorithm worked as expected
- Switching between GOES or EumetSat is possible and easier than expected
- The radio also did not get hot enough to shut itself off





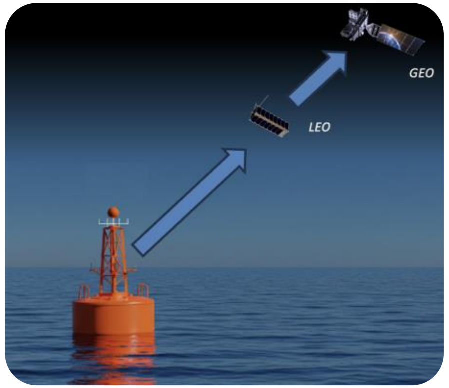
Applications



In-Space Environmental Monitoring Hosted Payload

Configuration: GTX-2.0SS Transmit Only + Space Weather Sensor

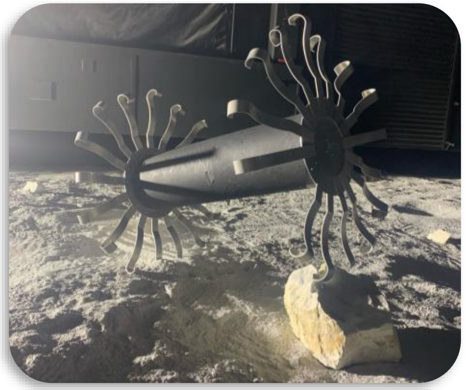
- When paired with a space environment sensor (i.e. a radiation monitor), provides a very low SWaP-C space weather monitoring payload with independent, license free communications using NOAA GOES or Eumetsat DCS – creating a true orbital DCS Data Collection Platform.
- Enables proliferated in-situ space weather monitoring on any bus, taking advantage of existing DCS data collection and distribution networks



LEO to GEO DCS Relay

Configuration: GTX-2.0SS Transmit + Receive (To Be Developed)

- With the addition of a paired GTX receiver, a LEO CubeSat could collect DCS transmissions outside of current GEO DCS coverage zones – for example, buoys in polar oceans – and relay them to NOAA GOES or Eumetsat DCS spacecraft



Courtesy of Microcom

Lunar & Martian Assets

Configuration: GTX-2.0SS Transmit + Receive (To Be Developed)

- Compatible with Mars communication network (e.g. MAVEN, MRO, ExoMars @ 401 MHz)
- Enables Nanosatellite-scale Martian surface missions to communicate with existing Martian data-relay infrastructure.