

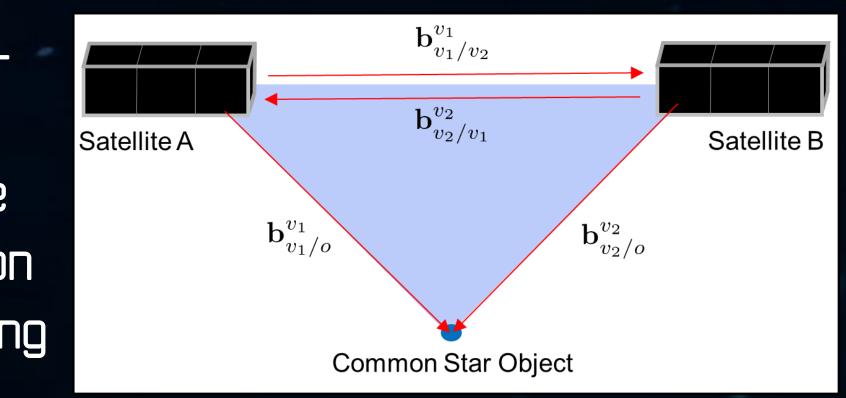


University at Buffalo Nanosatellite Laboratory



FALCON

FALCON is a two satellite mission being developed to test the ability to provide relative attitude and orbit information between two spacecraft using line-of-sight (LOS) and range



measurements. Such measurements can be taken via laser communication systems, which allow for precision attitude and orbit determination simply as a byproduct of laser communication systems. FALCON is a participant in the University Nanosatellite Program, sponsored by the Air Force Research Laboratory.

Mission Relevance

Formation-flying missions and constellations becoming increasingly

As constellations generate more data, increased communications capability is needed

- Laser communication allows for extremely high bandwidth and narrow beam width makes communications more secure
- Calculating orbit and relative attitude as a bi-product of existing optical communications will reduce both the mass and cost of future mis-

Optically based orbit calculations allow for navigation in GPS denied environments

Contact Information

Optical Payload

The payload on each of the two FALCON satellites includes a laser, lens, star tracker, and position sensing diode (PSD). Both satellites will link with the ground station to gather information on the other satellite's orbit to be used alongside input from the payload to determine its attitude. In order to calculate the orbit and relative attitude:

- . Light is shone from the laser diode through a collimating lens to reduce beam divergence
- . Light is received by a plano-convex lens then focused passed a band-

pass filter to eliminate

The light is received by a position sensing diode, a photosensitive de-

vice from which the line of sight vector can be

determined.

For a relative attitude solution to be formed, each satellite will need a line of sight vector to a common third object. For our mission, this is accomplished by using a star tracker onboard each satellite and finding a unit vector to a common star. Using the time between sending and receiving laser pulses to calculate the distance between the satellites, FALCON will be able to calculate its orbit without the need for a GPS re-

Ultra-Wideband Payload

As a secondary technical demonstration, each of the two FALCON satellites includes multiple Ultra-Wideband (UWB) transceivers. UWB radio communication is a relatively new technology that can provide precision positioning measurements between two or more transceivers. This allows a collection of these low cost modules to provide relative position and attitude estimates for spacecraft proximity operations. A low cost option produced by Decawave has been selected, which can provide data at a high update rate.

The UWB modules have an additional benefit, in that they are not unidirectional like the laser system is. Therefore, no prior knowledge of the relative spacecraft pose needs to be known in order to use them. The only requirement is that the UWB have a line of site to one another. The fact that they are not directional however, means that their range is limited to within only a few tens of kilometers for our purposes. At this range, the absolute orbit of each satellite is not observable, and so we will be estimating the relative orbit of one satellite with respect to an-

The UWB modules use multiple methods for obtaining the relative pose information.

- Two-way Time-of-Flight Ranging provides a measurement of the absolute distance between all the UWB modules
- Time delay of arrival provides the relative positioning of all the modules with respect to a single receiver
- Phase difference of arrival provides an angle of arrival measurement for a given receiver

These measurements can then be processed by onboard navigation filters for conducting proximity operations.

Developed in-house, the Little Free Radio (LFR) is an opensource compact telemetry, telecommand, and data radio designed for use in cubesats. LFR is designed to operate in the VHF and UHF amateur satellite bands, and is easily extensible to operation in nearby space research bands. It supports low and medium speed data streams, from 5 kbps up to 50 kbps. The data rate can be set dynamically in response to changing link conditions throughout a pass to maximize data

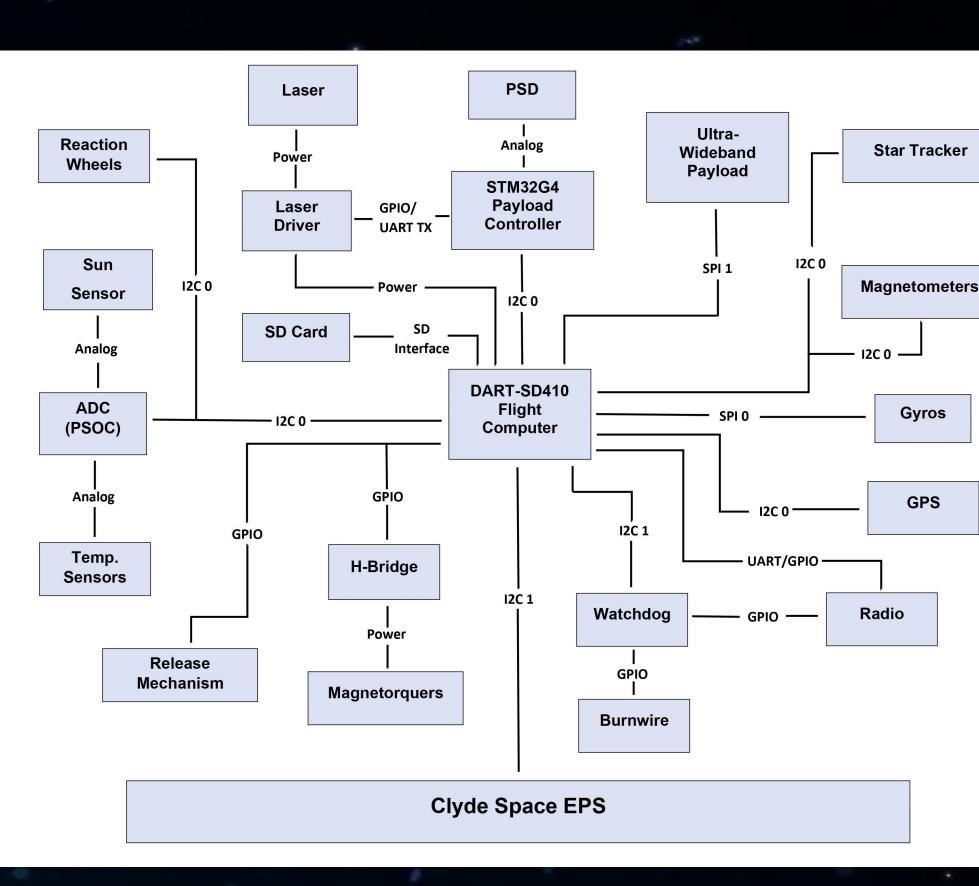
throughput. A custom, high efficiency power amplifier allows output power higher than comparable commercially available hardware, without the need for additional heat sinking. All schematics and documentation are available at:



ARCHITECTURE

The electronics on each of the two FALCON satellites have an identical ARM based flight computers. Each of the computers will be running NASA GSFC core flight system open-source operating system. The opti-

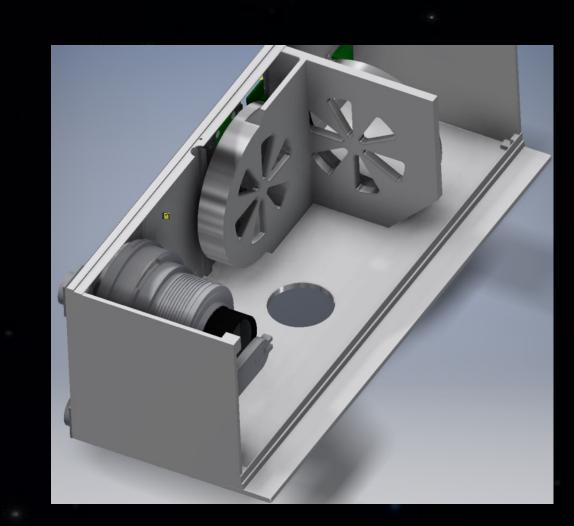
cal payload microcontroller is responsible for handling commands and telemetry with the position sensing diode (PSD) and laser. A custom C script is being developed in house to ensure all timing and accuracy requirements are met.

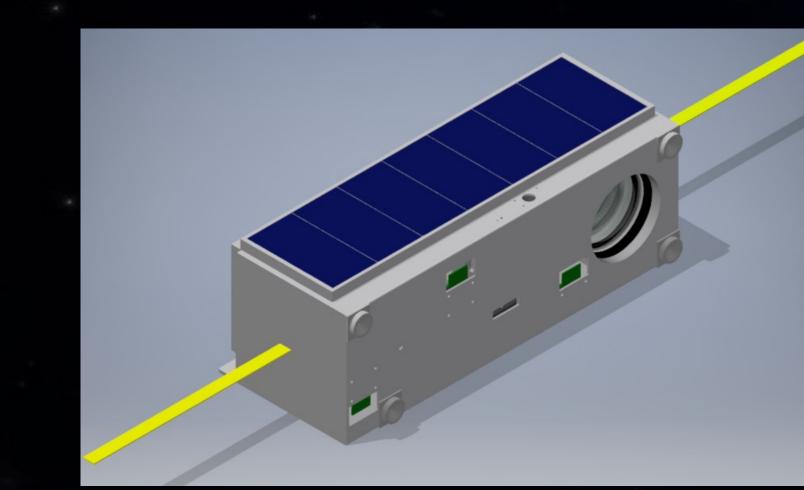




ADDITIVE MANUFACTURING

FALCON is composed of 2 satellites, each 3Us in size. They will separate during the mission to form a constellation. They contain 2 interior struts, one conventionally made, and one made used additive manufacturing, pictured below on the left. The additive manufacturing piece will contain the rings for two magnetorquers, mounting holes for 3 Cubespace Small+ reaction wheels and lightening holes. MOOG is assisting in the design and manufacturing of the structure using proprietary additive manufacturing technologies.





ELECTRICAL POWER SYSTEM

Using battery charge/discharge curves, solar cell IV curves, and a satellite load profile, the entire power system can be simulated and properly sized. The graph below highlights the state of charge (SOC) of the battery, satellite power consumption, and solar power produc-

