# PRECISE ORBIT DETERMINATION OF THE RANGING AND NANOSATELLITE GUIDANCE EXPERIMENT (RANGE)


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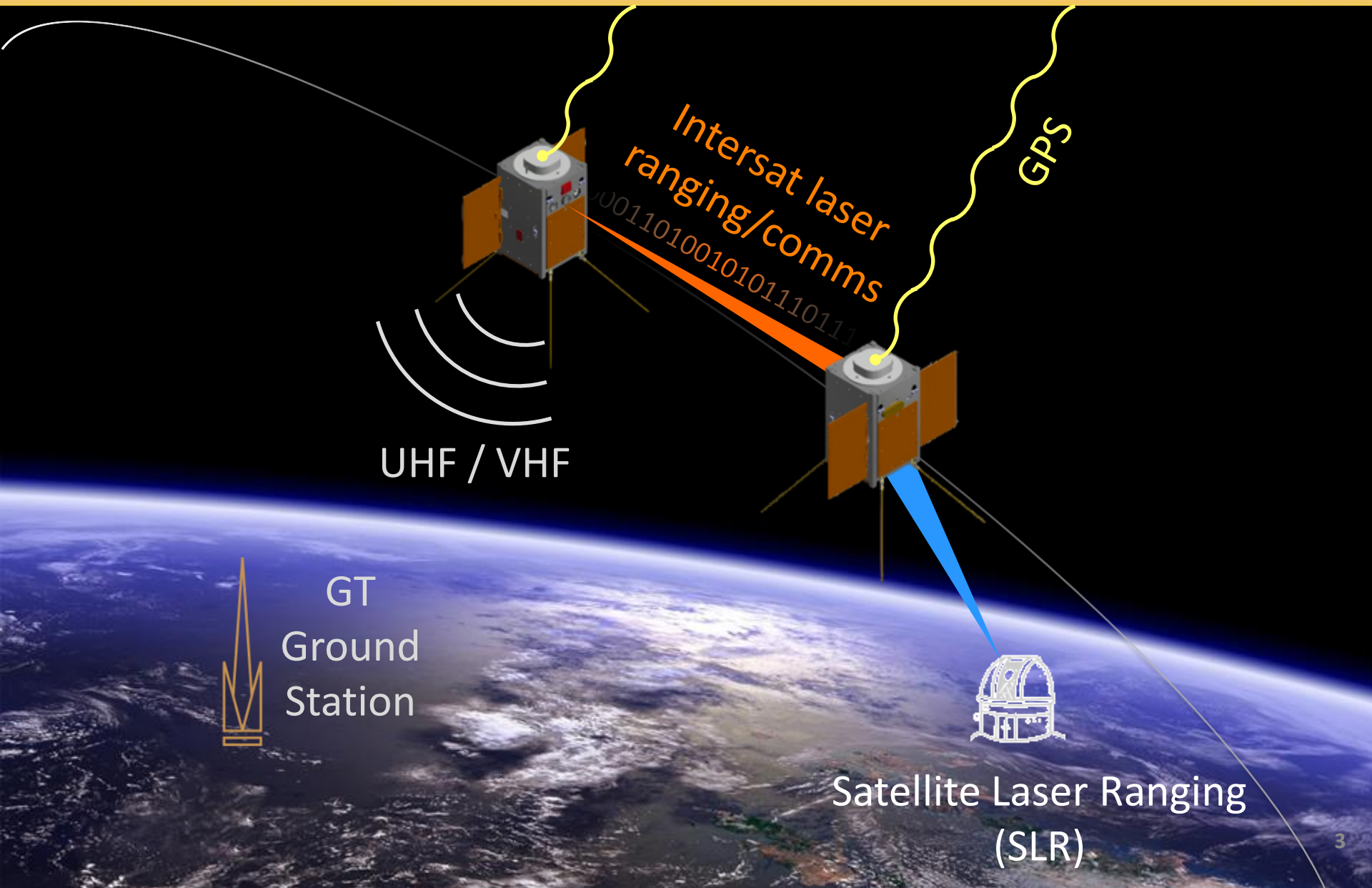
# RANGE - MISSION OVERVIEW

- Two 1.5U satellite formation
- Selected in 2015 for a launch opportunity through the Terra Bella (formerly Skybox, now Planet) University Cubesat Partnership
- Mission objectives
  - Improve absolute and relative positioning capabilities of nanosats
  - Explore propulsion-less (autonomous) formation control techniques
  - Transmit low-rate optical (laser) communications
- Innovations
  - Demonstrate cm-level POD for cubesats
  - Evaluate performance of a miniaturized atomic clock
  - Autonomous formation control

# RANGE - CONOPS



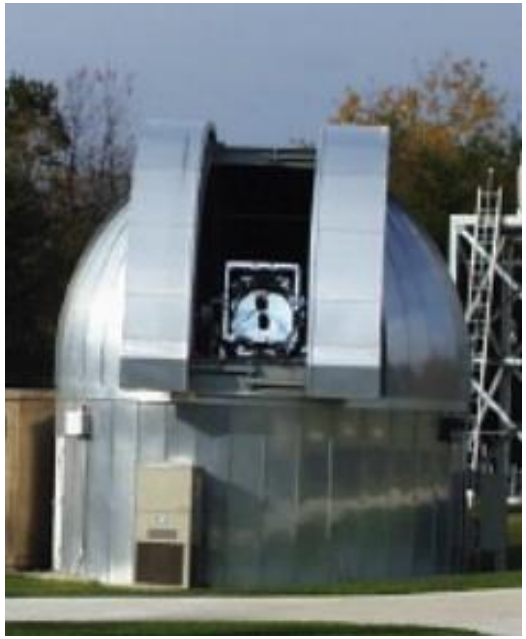
# RANGE - PAYLOAD

- Primary payloads
  - Novatel OEM628 Receiver (L1/L2)
  - Chip Scale Atomic Clock (CSAC)
    - < 2.5e-11 ADEV over 10s

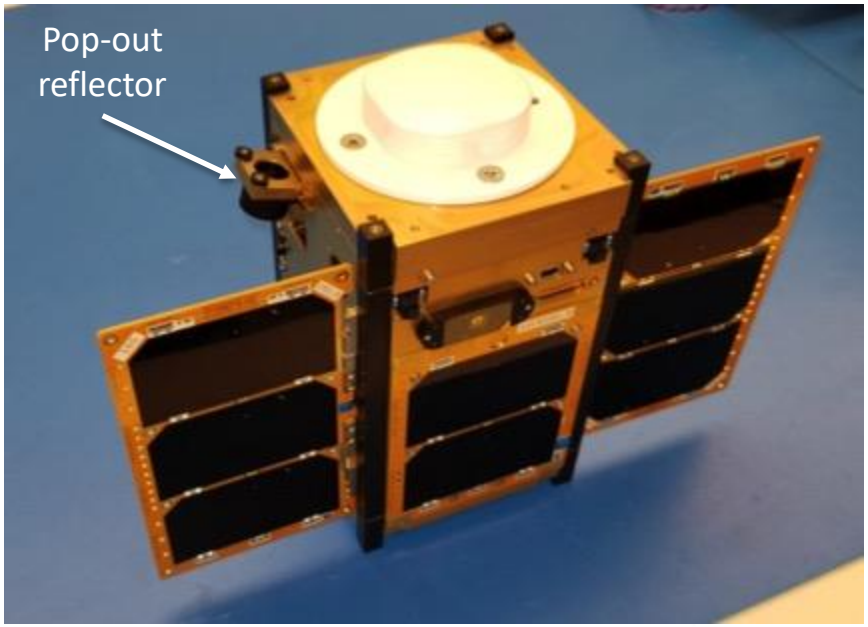
Novatel Receiver

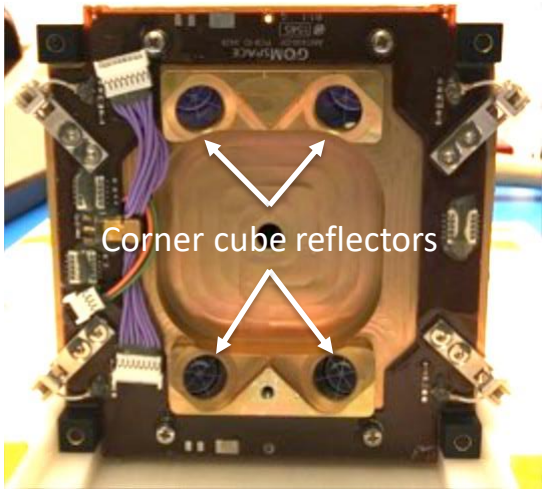

CSAC


- Orbit verification through ground-based satellite laser ranging (SLR)—NRL & ILRS
  - NRL 1m telescope, <2 arcsec pointing error
  - Fast switching for SLR to tandem satellites
  - Sub-cm SLR precision @ 532nm

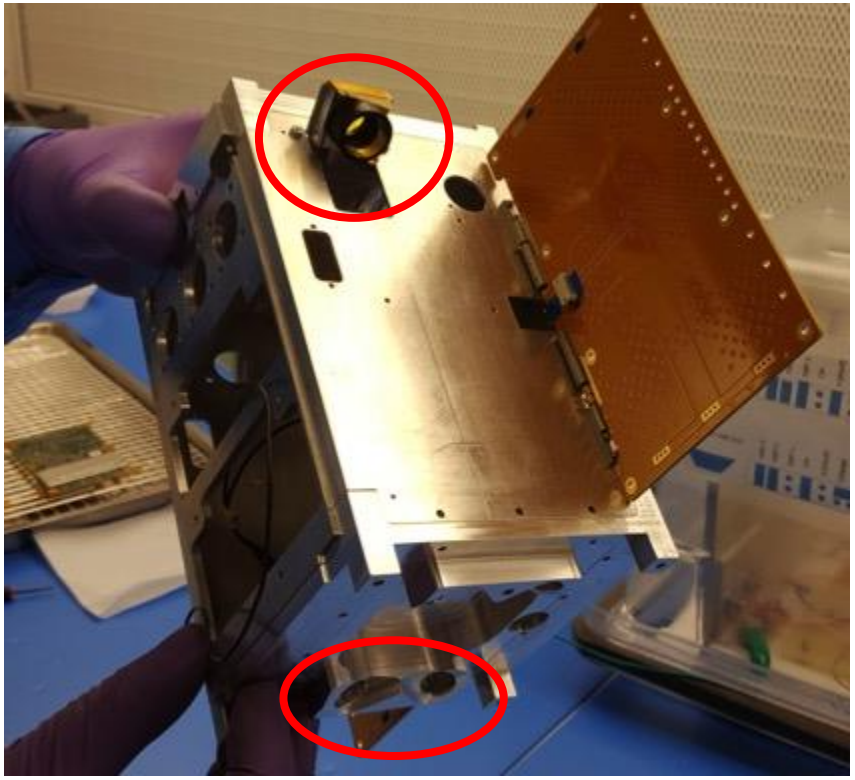


# SLR TRACKING



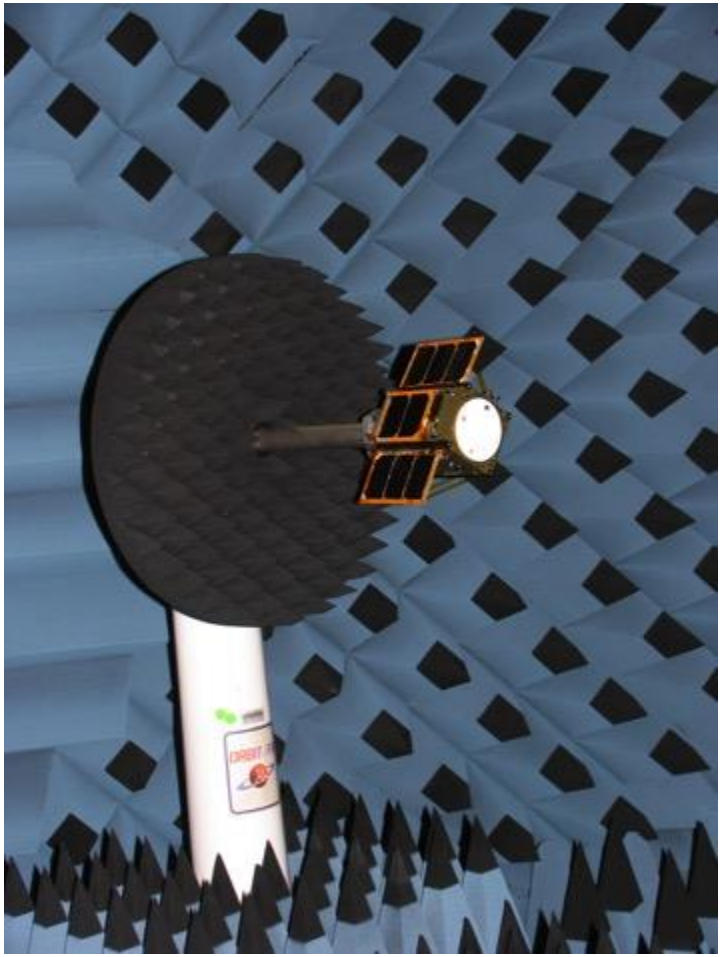




- Corner-cube retro-reflector array on nadir panel will permit SLR tracking
- Pop-out reflector aligned with two of the nadir retros to allow for attitude determination experiments



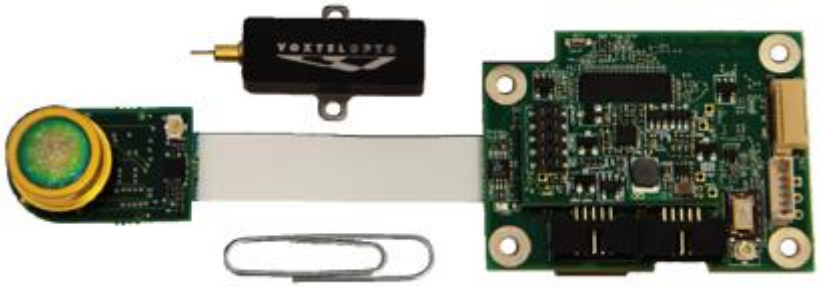
# ANTENNA CHARACTERIZATION

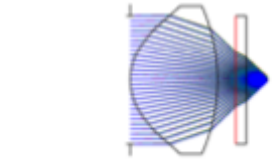
- RANGE GPS antenna testing at the NRL Anechoic chamber
- Tests ran with and without structure to assess potential multipath error
- Resulting PCV maps will help improve POD

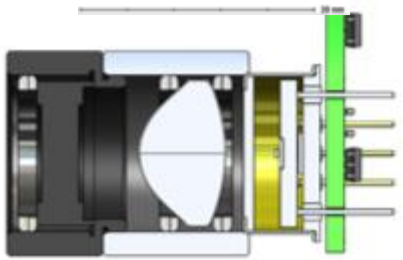


# RANGE - PAYLOAD

- Laser Rx/Tx System
  - Made by Voxtel
  - 25 kW, 4 ns pulses
  - APD sensitive to nW
  - Custom optics design (GTRI)
  - 2.5$^{o}$ beam divergence to account for coarse s/c pointing
  - Class 1 (eye-safe), 1535nm

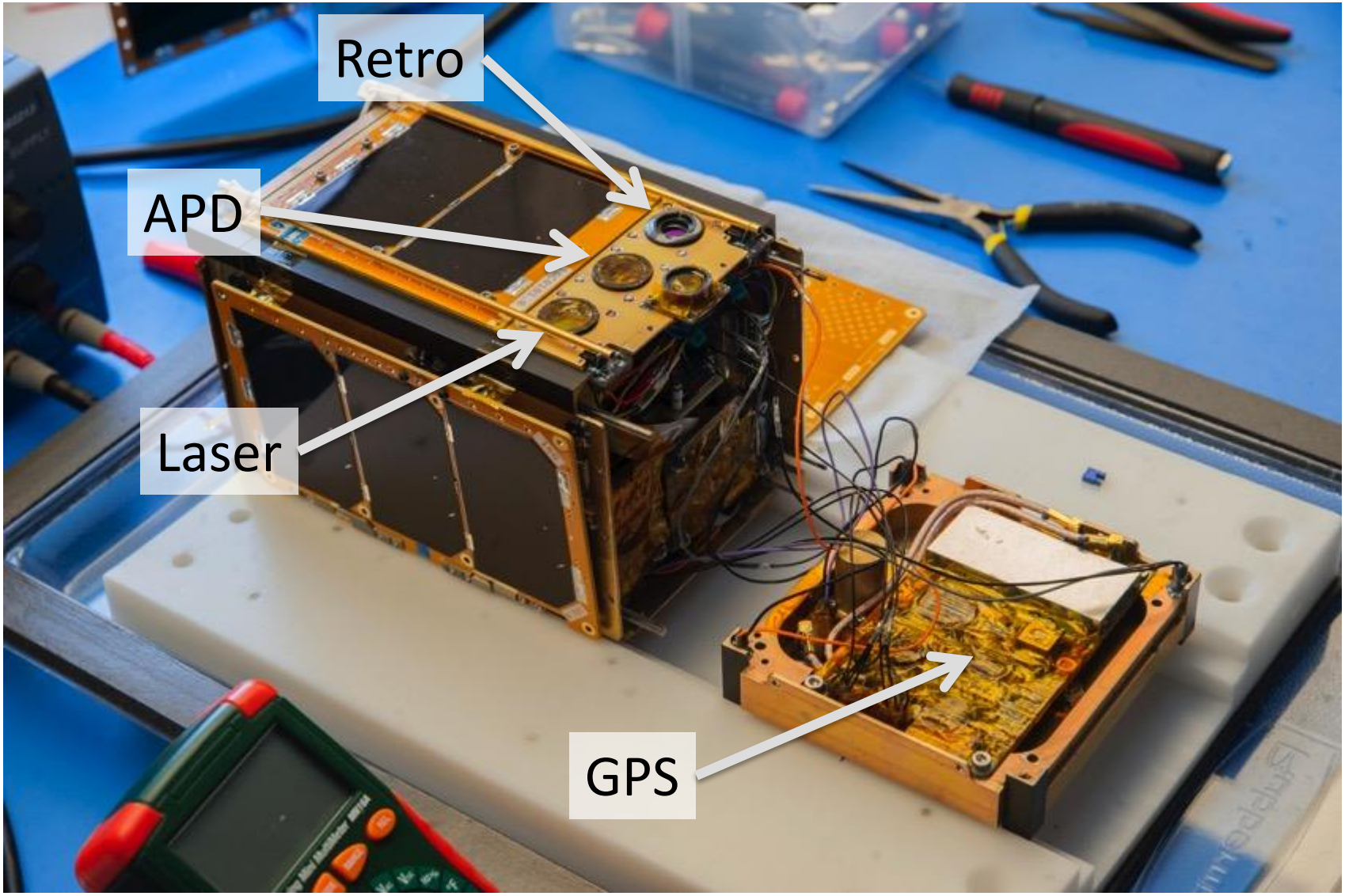






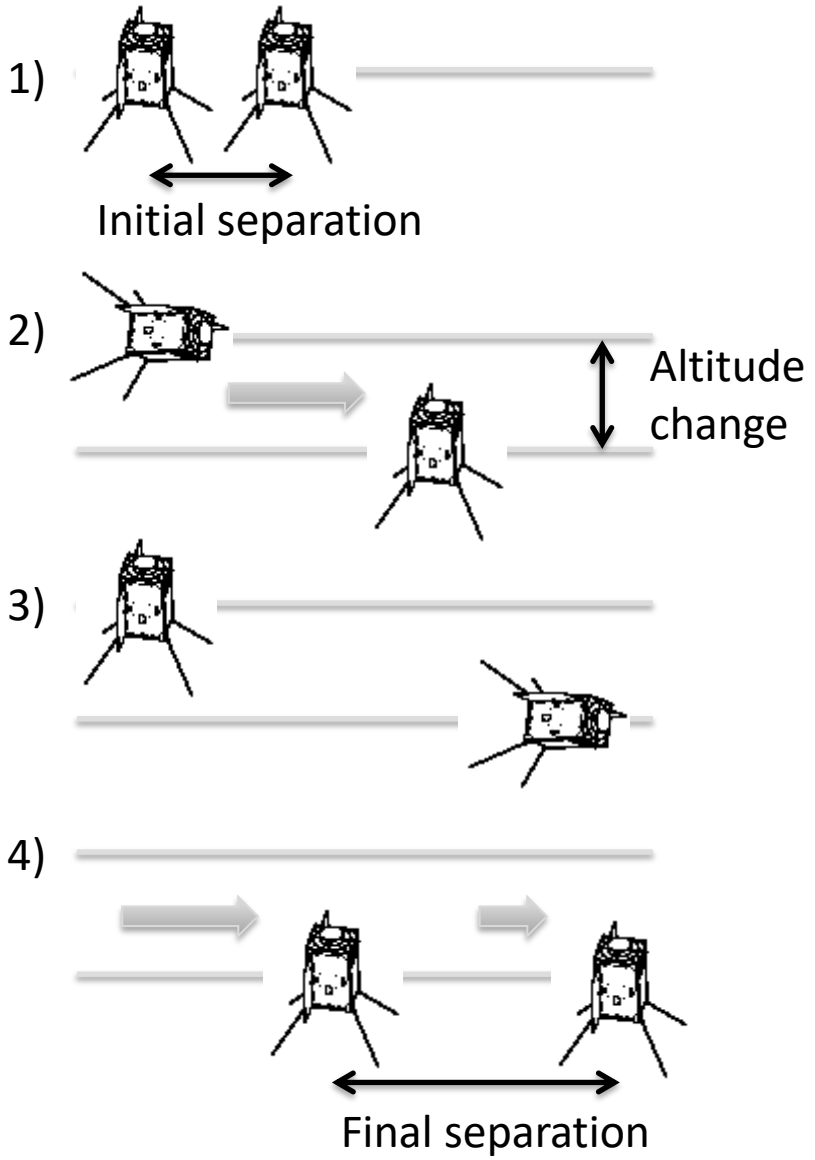
- Est. one-way detections to 500 km, dual-way detections < 1km
- System will be tested as a low-rate laser communications

# RANGE - PAYLOAD



# RANGE – FORMATION CONTROL

- Satellites will have no propulsion system
- Inter-satellite distance (in plane) will be controlled through differential drag
  - Change in drag ratio (orientation) between the two satellites causes a relative motion
  - Well described in the literature, but few mission examples (Planet Labs, Aerospace AC6)
- Current mission plan will vary distance from hundreds to thousands of meters



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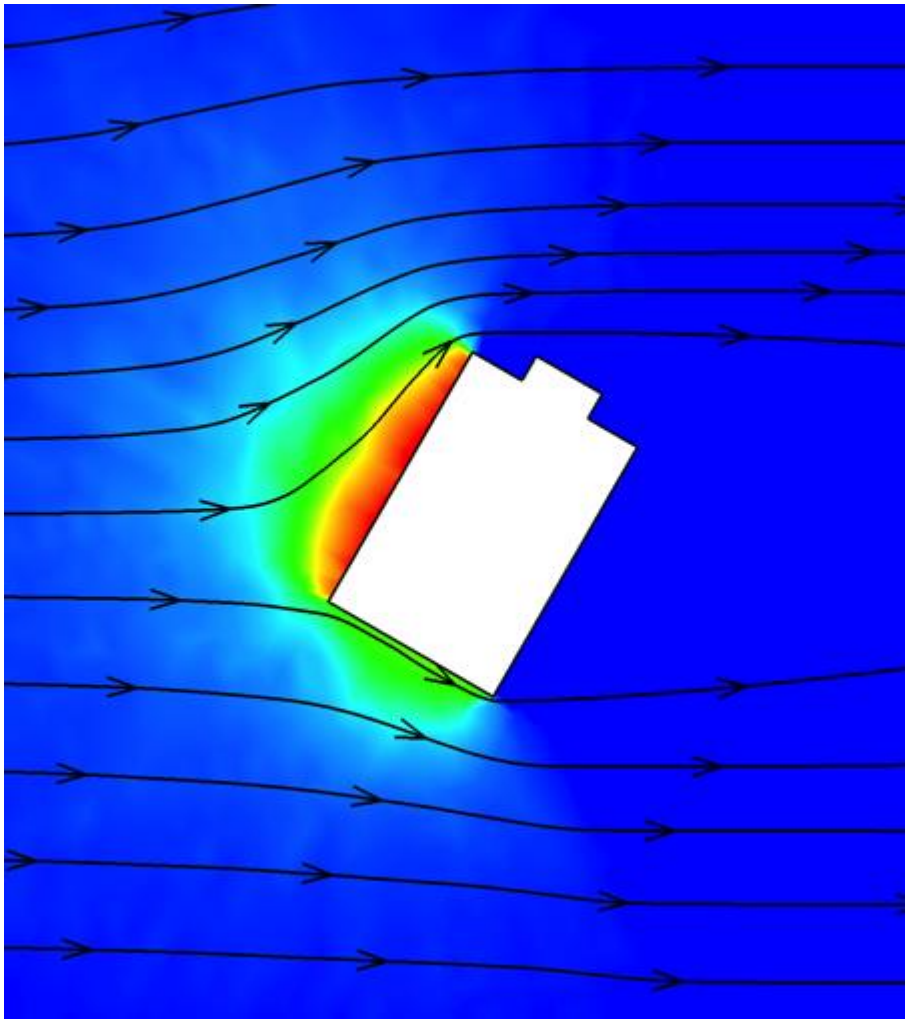
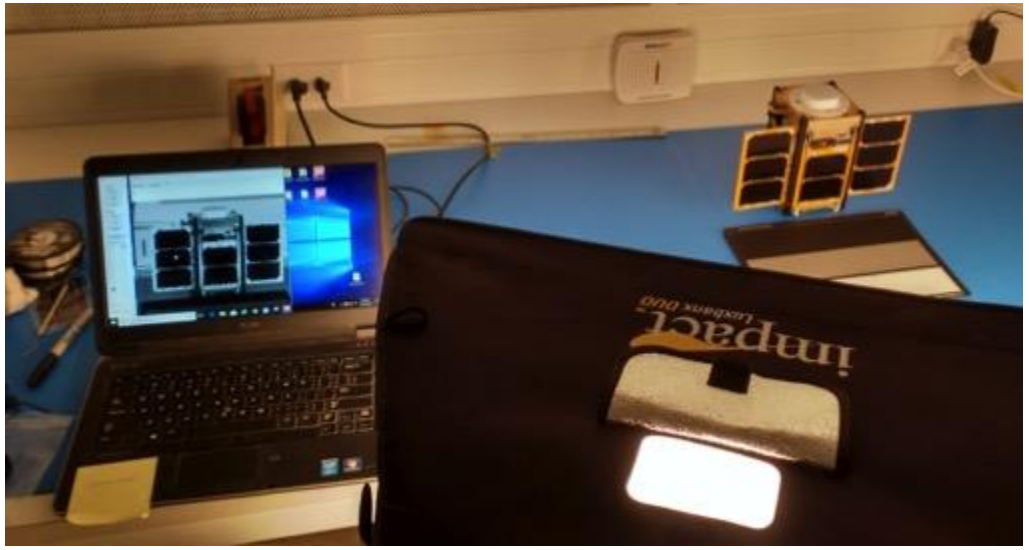


Image: K. Hart

- Aerodynamics modeled using NASA's DSMC Analysis Code (DAC)
- Explored forces on satellite in free molecular flow
- Simulations show noticeable differences from drag forces modeled by traditional atmospheric models
- See Hart et al, SPACE2016, AIAA 2016-5520, 2016

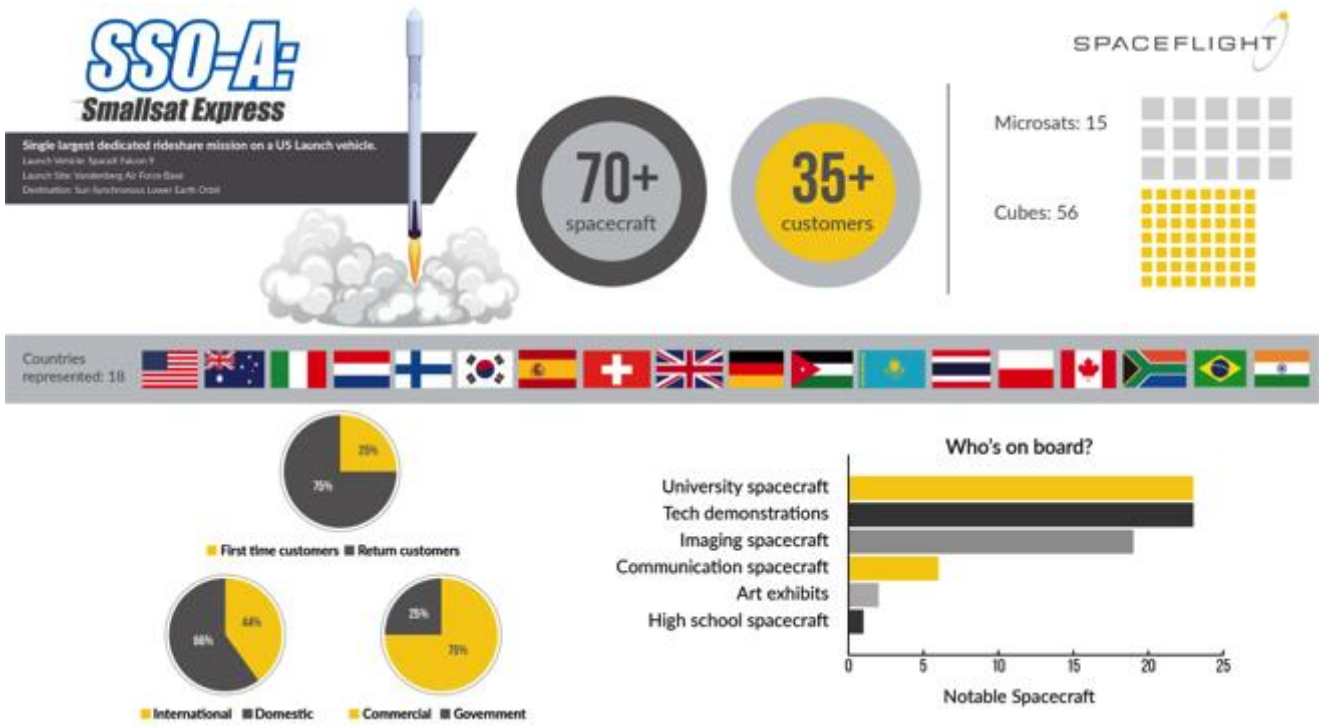
# SPACE SITUATIONAL AWARENESS

- RANGE satellites have also been characterized using a hyperspectral imager
- Using Georgia Tech Space Object Research Telescope (GT-SORT), will also attempt to optically track RANGE.
- Having apriori knowledge of RANGE's position and attitude should help improve iOD estimates and processing algorithms

# RANGE – UPDATE/STATUS

- Launch scheduled for mid- to late-November, 2018, from Vandenberg AFB
- Launch vehicle a SpaceX Falcon-9 Block 5
- Will go up as part of Spaceflight's SSO-A mission
  - 70+ other small satellites will be deployed on this same mission!
  - The largest single rideshare mission on a US-based launch vehicle
- Satellites have been delivered and integrated into deployer




Graphic courtesy Spaceflight Inc: http://spaceflight.com/sso-a/

# SCIENCE APPLICATION - GEODESY

- Constellations of non-dedicated satellites should be able to observe large scale (> 1000 km), short period (< 1 month) mass transport signals
  - This signal spectrum less observable with GRACE due to inherent limitations in ground track coverage
  - Fully complementary to dedicated gravity field missions
  - Particularly valuable to atmospheric and ocean sciences

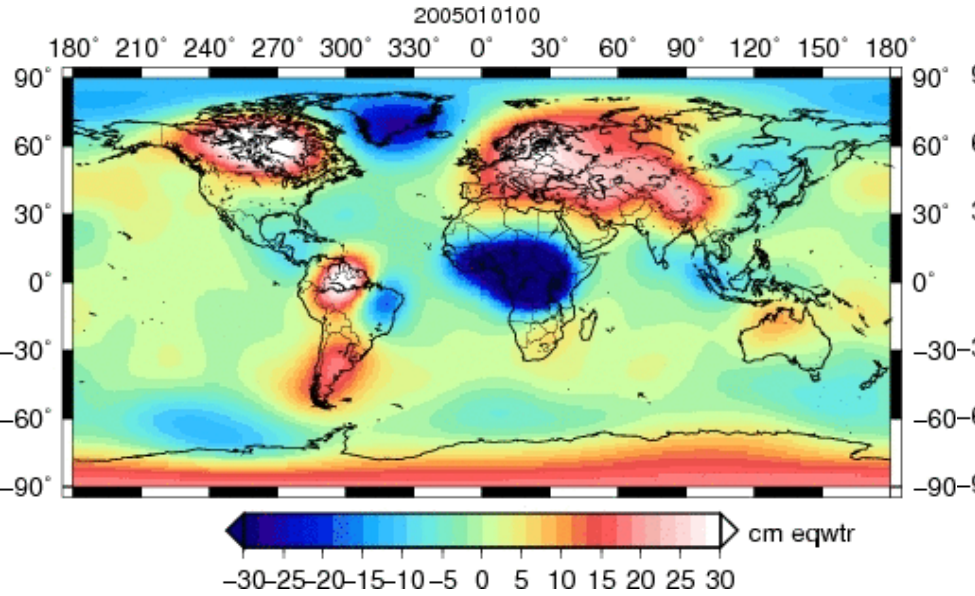
- Positioning accuracy (i.e., POD) driving factor for performance
  - 2-3 cm positioning sufficient for observing large scale features
  - Motivating factor behind RANGE target POD

# SCIENCE APPLICATION - GEODESY

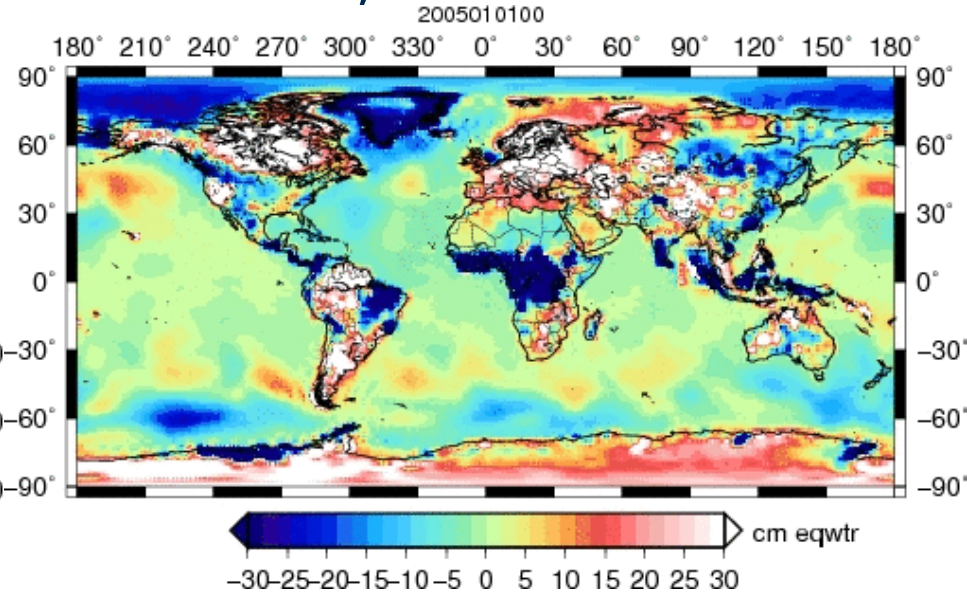
U.S. NAVAL RESEARCH LABORATORY

Georgia Tech

## Constellation




## Model, Full Resolution




- Left panel represents simulated gravity models recovered from 66-satellite constellation using 2-3 cm 3D RMS POD uncertainty
  - Ditmar et al, J. Geodesy, 2007; Gunter et al, J. Spacecraft & Rockets, 2011
- Right panel is truth model derived using high-resolution, 6-hourly atmosphere, ocean, ice, hydrology, and solid-earth variations derived from a coupled Earth-system model
  - Gruber et al, ESSD, 2011

# CONCLUSIONS

- RANGE will push the state-of-the-art for the precise orbit determination capabilities of small satellites
  - Dual-frequency GPS
  - Ground-based SLR
  - JSPoC tracking
  - Optical tracking

- The results of the mission should improve the command and control of future nanosatellites, potentially enabling new classes of mission concepts

# QUESTIONS?

- For more information, contact:

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