

DrEAM Status Approaching Aeroshell Integration

IPPW

June 24th, 2026

Aaron Brandis

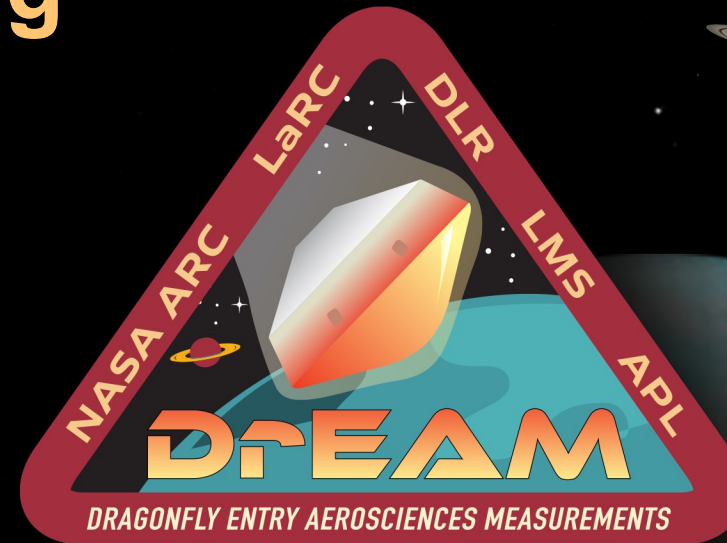
NASA Ames Research Center

DrEAM Investigation Lead

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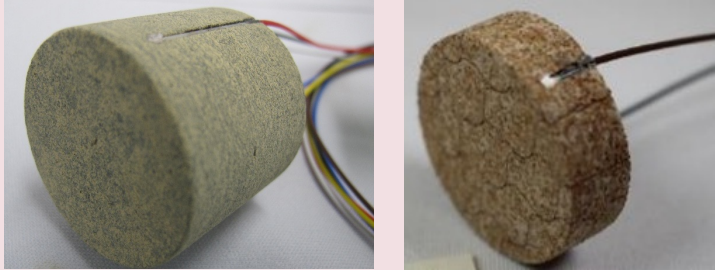
¹NASA Ames, ²Hyperspace Technologies, ³DLR, ⁴NASA Langley, ⁵AMA, ⁶Jacobs.



DrEAM Instrumentation Suite

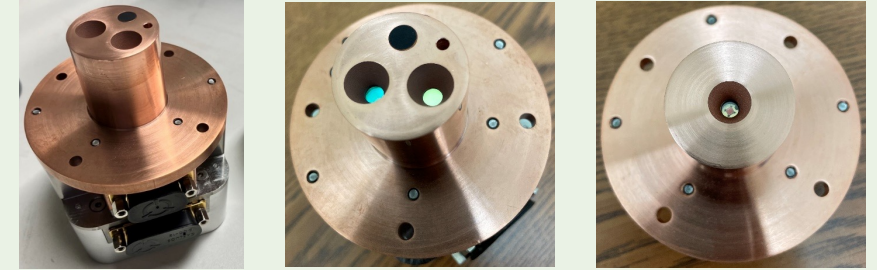
Dragonfly Sensors for Thermal Reconstruction (DragSTR)

- (NASA) In-depth thermocouples to back out the aerothermal environment and understand the Thermal Protection System (TPS) material response



COmbined Sensor System for Titan Atmosphere (COSSTA)

- (DLR) Radiometers, total heat flux sensors, and pressure transducers on the backshell to quantify radiative heating from CN and vehicle dynamics

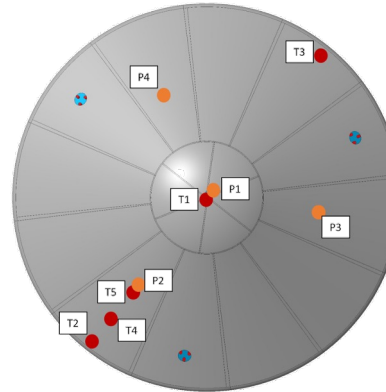


Dragonfly Atmospheric Flight Transducers (DrAFT)

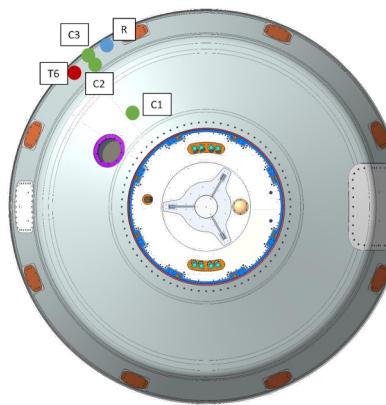
- (NASA) Hypersonic pressure transducers on the forebody for atmospheric and aerodynamic reconstruction



Forebody



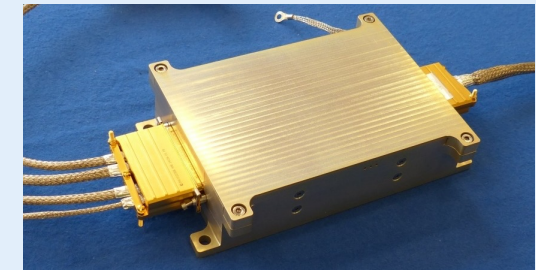
Backshell



- DrAFT (P) ● DragSTR (T) ● COSSTA Radiometer (R)
- COSSTA Heat Flux and Pressure (C)

Data Acquisition System (DAS)

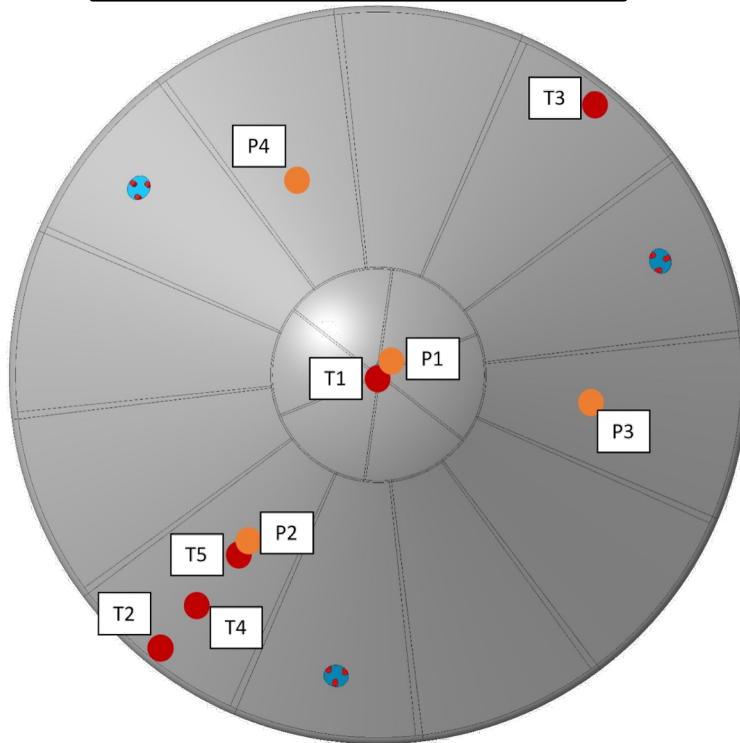
- (DLR) Two boxes (1) Digital Processing Unit and (2) Multiplexing Signal Conditioner which collect DrEAM instrumentation data for transmission back to Earth



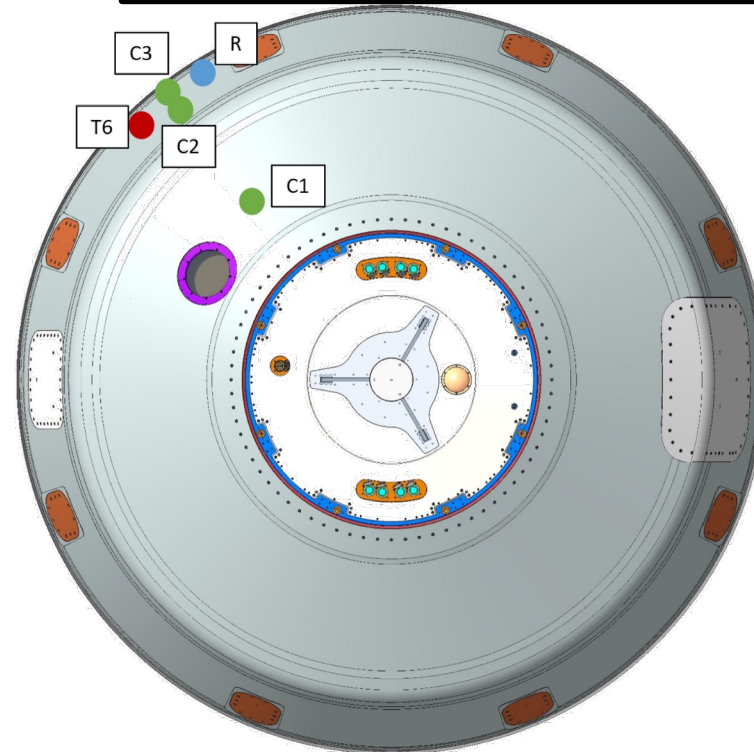
DrEAM Sensor Layout

NASA and ESA entered Titan once before as part of the Cassini/Huygens mission. The uncertainty in radiative heating and CH_4 abundance was a significant entry risk. DrEAM will represent the first Titan EDL data to be measured.

Forebody - PICA

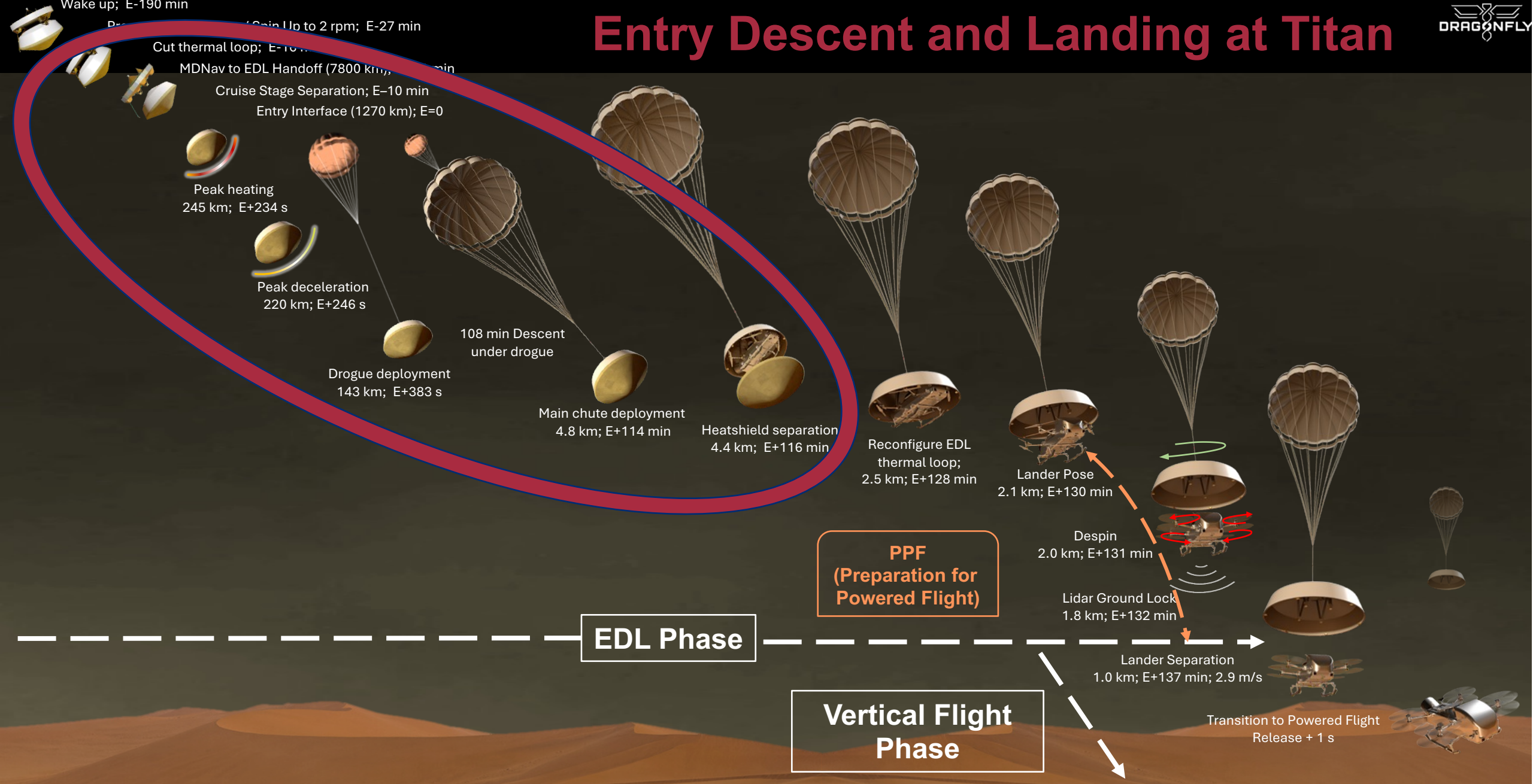


Backshell – SLA561V



- DrAFT (P) ● DragSTR (T) ● COSSTA Radiometer (R)
- COSSTA Heat Flux and Pressure (C)

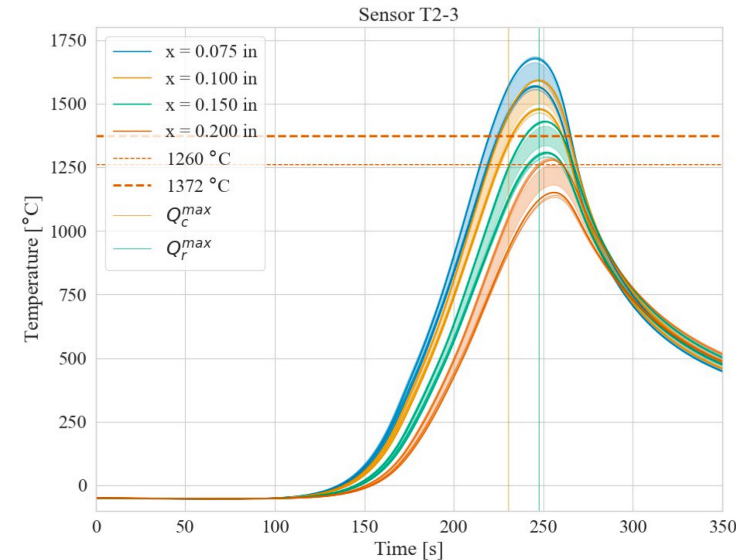
Entry Descent and Landing at Titan



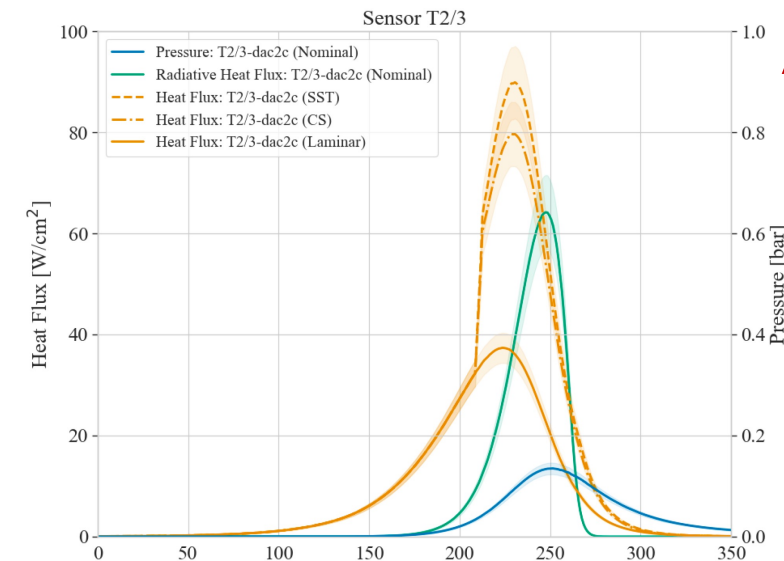
* Times and altitudes referenced to DAC-2A* CBE Mean

DrEAM Thermocouple Depths

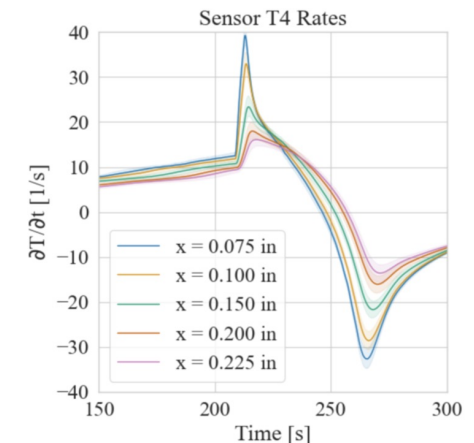
- All Thermocouples (TCs) are Type K to minimize need for Cold Junction Compensation (CJC) channels
- We have finalized and documented the DragSTR heatshield thermocouple depths
 - Both margined and best estimated environments were used in the analysis
 - Best estimated environments were used for the near surface TC, and margined environments for the in-depth TC
- Ability to measure a rapid change in heating due to transition to turbulence based on MEDLI2 data.



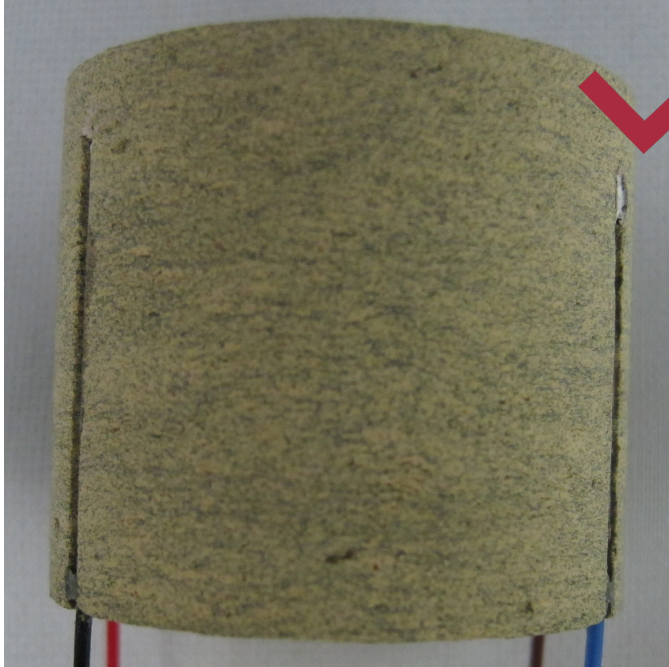
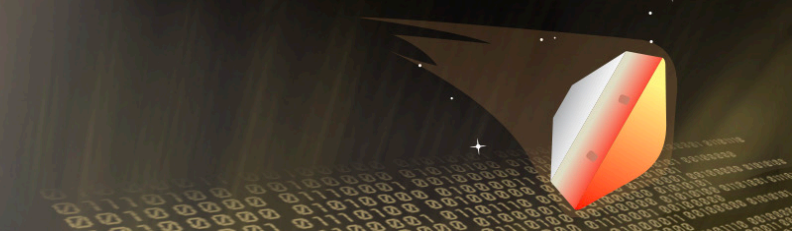
Assessing TC depth



Assessing transition



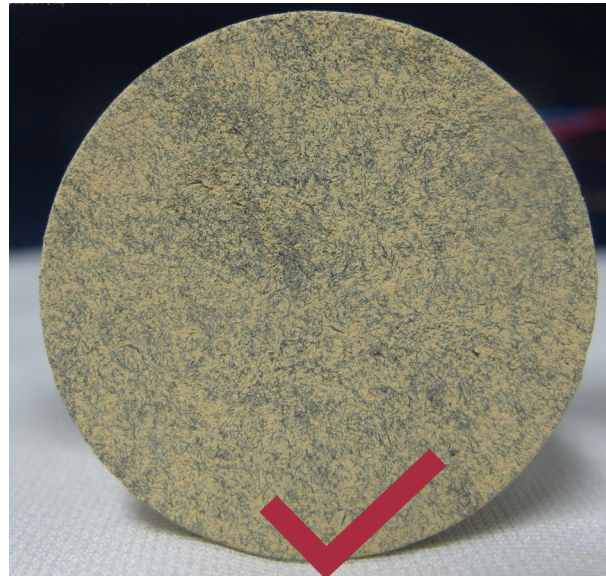
DragSTR Flight Hardware Selection



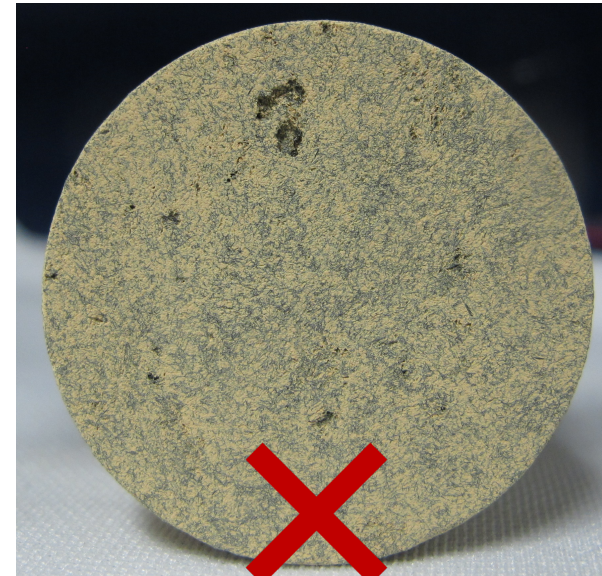
Flight TC2

- Compare as installed TC depths to planned
- Review X-Ray for TC bead and wire installation
- Check for significant discoloration/ freckles or cavities in the TC plug PICA-D
- Calculate and select uniform PICA-D densities

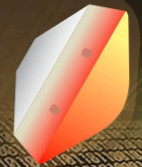
Flight TC1



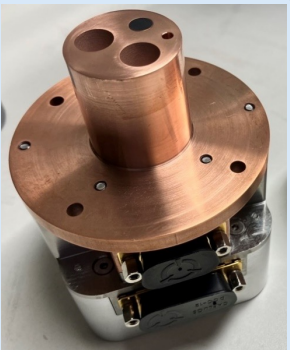
Science TC



COSSTA Do No Harm Testing (R. Miller IPPW 2024)



Step 1.
Receive 5
COSSTA
sensors from DLR
and perform
functional checks



Step 2. Ship
5 COSSTA
sensors to
LM for
installation in
12"x12" SLA
test panels



Step 4.
Machine
test panels
and
assemble
6" dia. flat
face arc jet
models

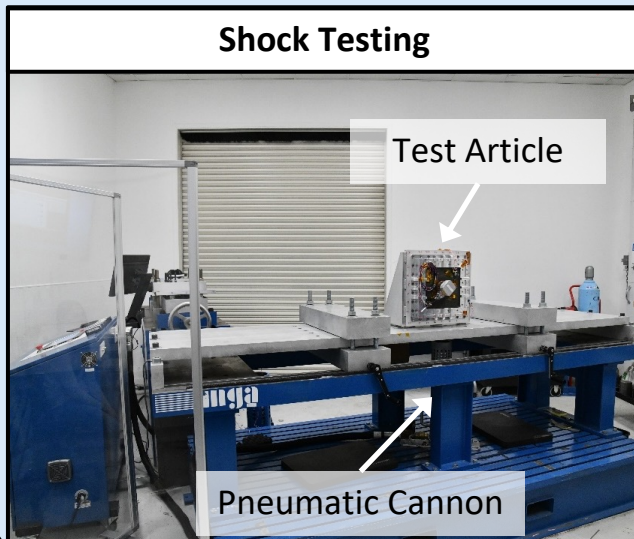


Step 6.
Perform
post-test
inspections
and
functional
checks

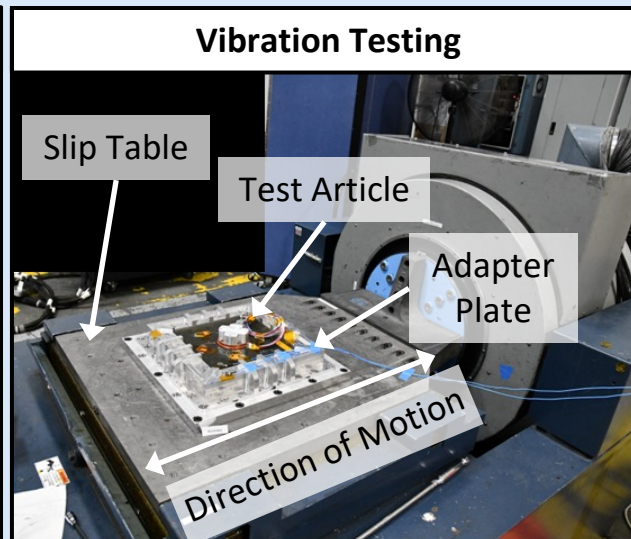


Step 3. Receive 7 test panels (5 with COSSTA sensors, 2 blank) from LM and perform DNH environmental testing

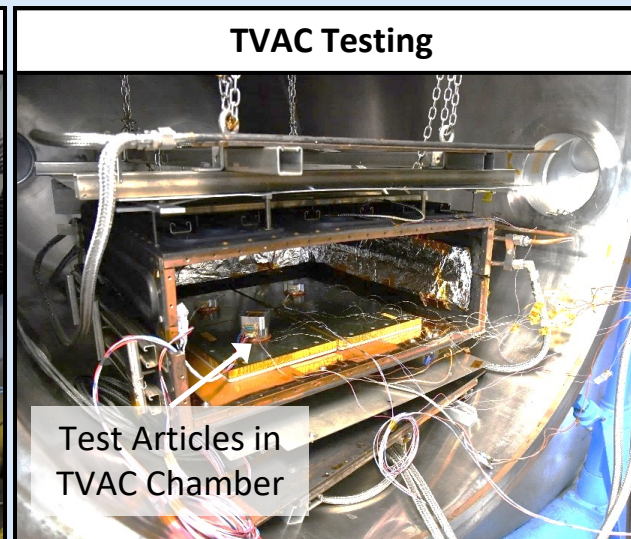
Shock Testing



Vibration Testing

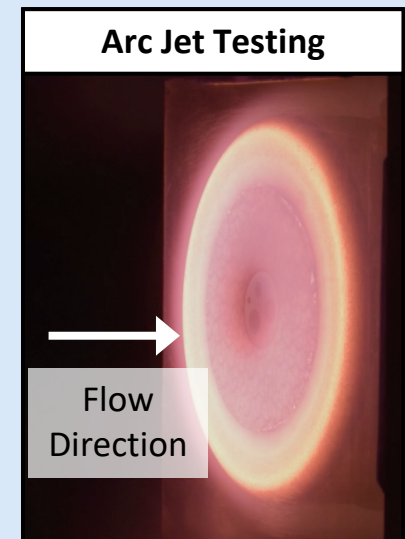


TVAC Testing



Step 5. Perform arc jet testing

Arc Jet Testing

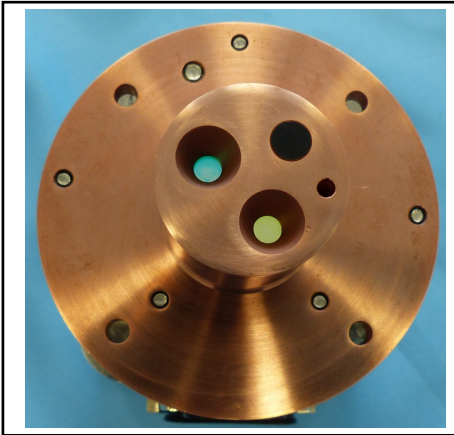


COSSTA Flight Hardware

Depending on the sensor location different sensor configurations are used:

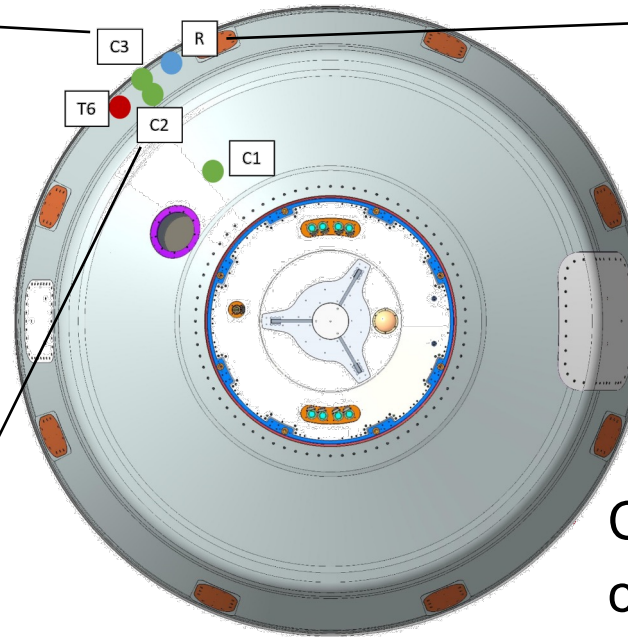
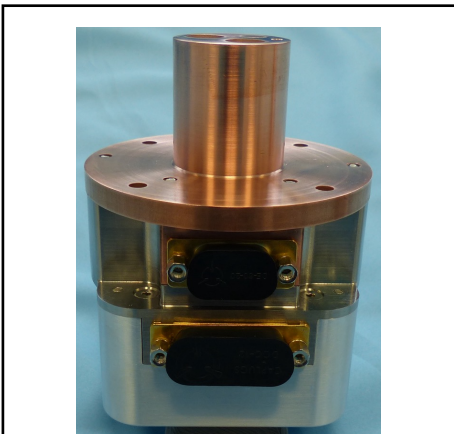
Aerothermal sensor C3

- Total heat flux sensor
- Pressure sensor
- Narrow-band radiometers (2x)



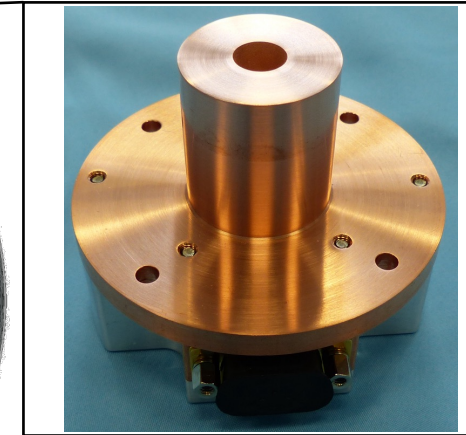
Aerothermal sensor C2

- Pressure sensor (2x)
- Narrowband radiometers (2x)



- DragSTR (T)
- DrAFT (P)
- COSSTA Aerothermal (C) & Broadband Radiometer (R)

C1 delivered. Not shown on this slide



Broadband Radiometer

- Total radiative heat flux sensor

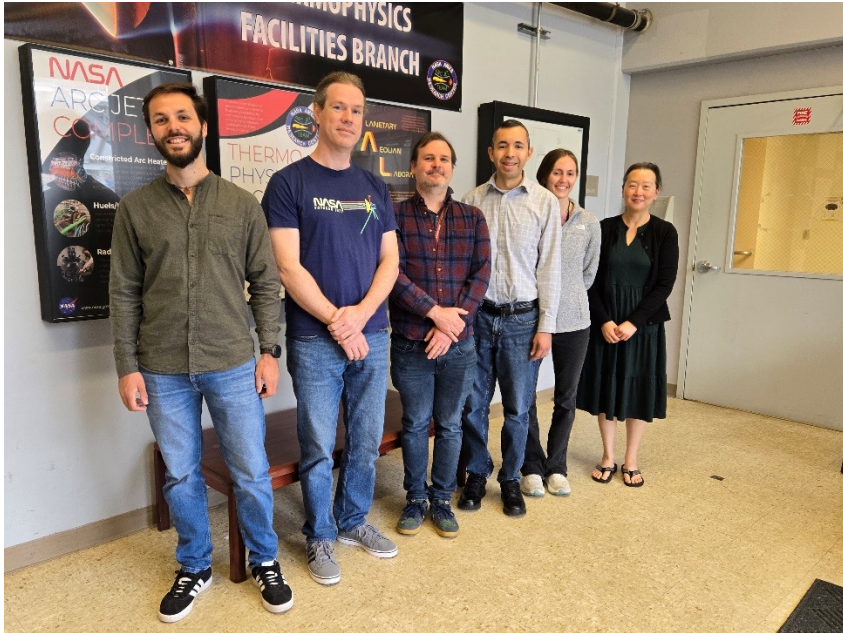
COSSTA pressure sensor calibration completed.

- COSSTA heat flux calibration at DLR and final assembly January

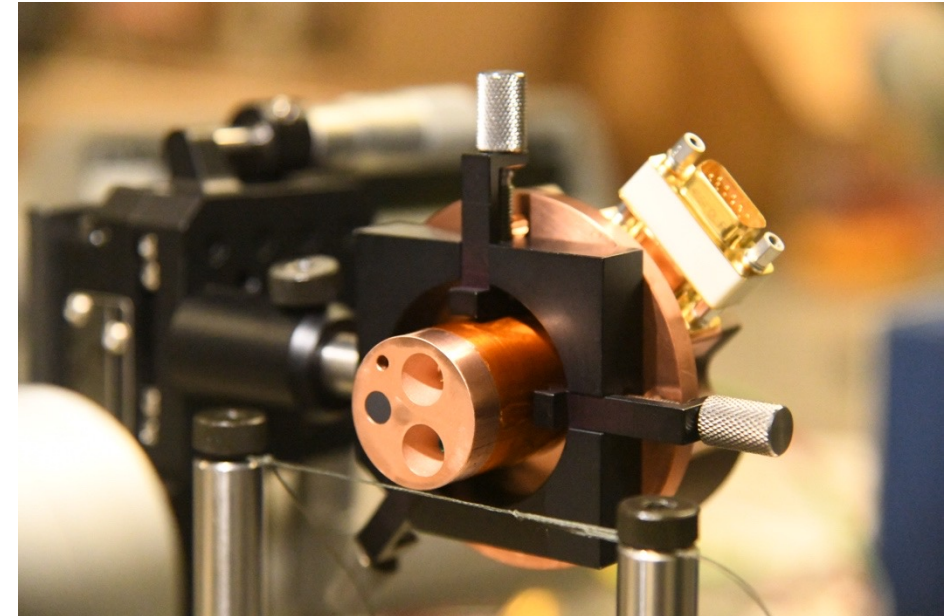
**DLR delivered flight
COSSTA sensors to NASA
Ames in March**

COSSTA Flight Sensors Delivered

- The four flight COSSTA sensors delivered to Ames in March.
- The sensors underwent a successful receiving inspection at Ames and followed by angular characterization (view angle dependence of the sensing element), as well as the absolute calibration for the radiant intensity using the quartz lamp bank and laser-driven light source.



DLR & NASA team at Ames



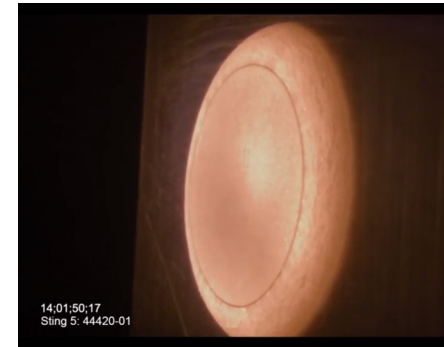
Angular characterization of the COSSTA sensors using the Laser Driven Light Source.

DrAFT Do No Harm Testing

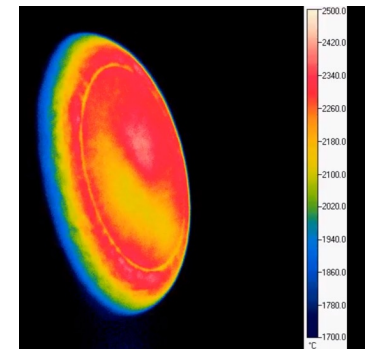
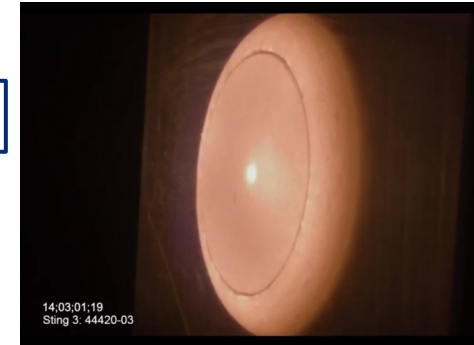
- Re-purposed leftover MEDLI2 MEADS stagnation coupons
 - Test coupons were built by LMS containing flight-like internal hardware (3.5" dia. flat-face PICA-D geometry)
 - Total of five Type K TCs
- 4 test models with pressure port hole
 - PICA component of original test coupon was removed with CNC machining operation and replaced with PICA-D
- 2 “blank models” with no pressure port hole
 - Serve as a control for comparison of PICA response and TC temperatures



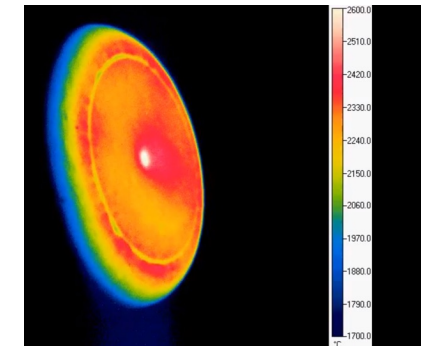
Surface temperature around 2500 °C in both cases



Video



IR Camera



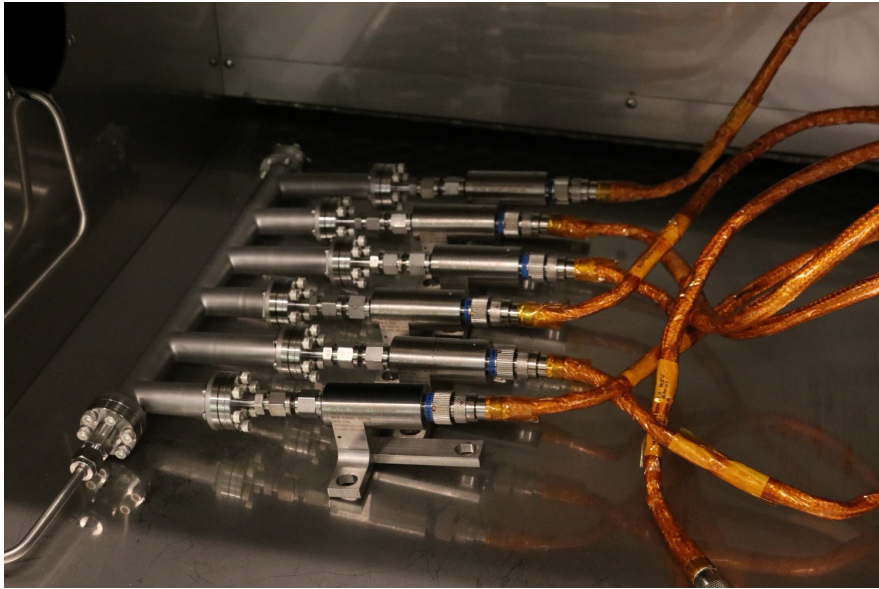
$(q_{hw} \approx 300 \text{ W/cm}^2, p_{stag} \approx 31 \text{ kPa}, 49 \text{ sec exposure})$

Test successful – post test hole size within requirements

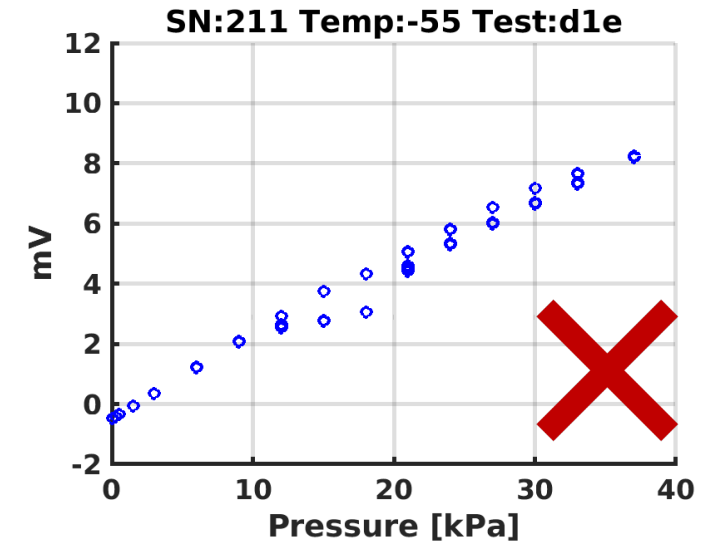
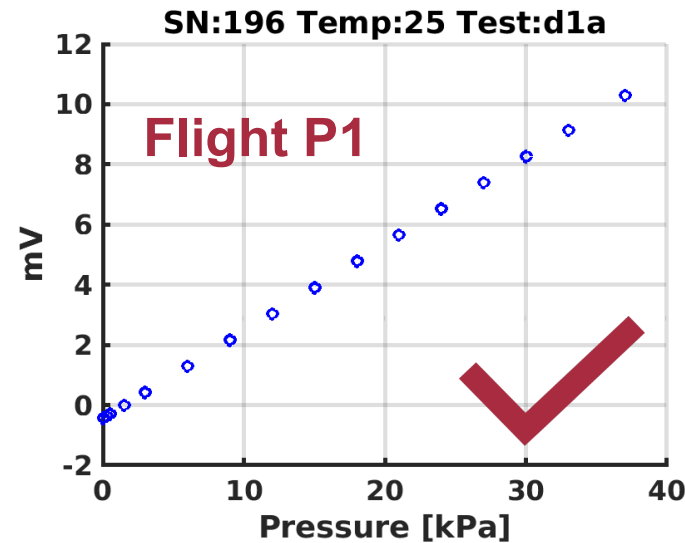
DrAFT Testing and Flight Lot



- The Dragonfly Atmospheric Flight Transducers (DrAFT) were tested for conducted emissions at NASA Langley's EMC Test Facility Dec. 16 – 17, 2024.
 - All 6 sensors passed, with no exceedances above Dragonfly defined limits.
- DrAFT thermal vacuum testing completed
 - Pressure sensors were tested both warmer and colder than for previous missions (MEDLI, MEDLI2) to meet Dragonfly temperature limits.



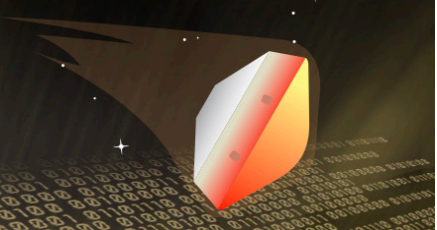
Flight and spare DrAFT sensors



Setting up for TVAC test along with TC read outs

First time automating entry pressure profile simulation with flight sensors

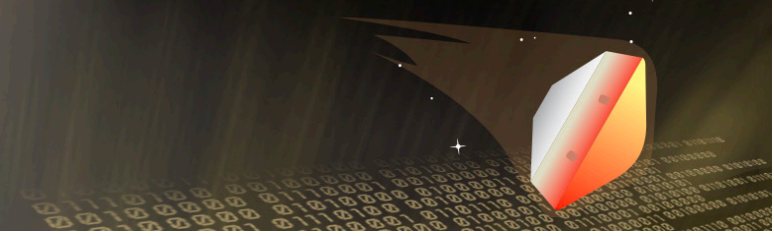
Before We Talk About 2026...where did we start...



- We started talking about a New Frontiers proposal to Titan with APL in 2016.
- ESI discussions started at this time. It went through a few name iterations based on MEDLI: DEDLI, TEDLI
- This table was included in the early submissions (now almost 10 years old)
- There have been variations over time, but compared to where we started, we are now on the verge of delivering flight hardware for nearly all the elements we originally planned.
 - Down one total heat flux and pressure location on the backshell
 - Up increased pressure range with FMI

ESI Goals	ESI Priority (based on call)	Measurement details	Instrument/Sensor	Heritage
Aerothermal Environment and TPS (forebody)				
Aerothermal Environment	High	Near-surface thermocouples as a function of time at 5 locations	TISP PICA plugs	MSL
TPS Response	High	In-depth thermocouples as a function of time at 5 locations	TISP PICA plugs	MSL
Aerothermal Environment and TPS (afterbody)				
Aerothermal Environment	High	Total heat flux sensors as a function of time at 3 locations.	COMARS heat flux sensors	Schiaparelli
Aerothermal Environment	High	Near-surface thermocouple as a function of time at 1 location	TISP SLA plug	MSL
Aerothermal Environment	High	In-depth thermocouple as a function of time at 1 location	TISP SLA plug	MSL
Radiation	Low	Broadband radiometer heat flux as a function of time.	COMARS broadband radiative heat flux sensor	Schiaparelli
Atmosphere, Aerodynamics, and Flight Dynamics				
Atmospheric Density, Dynamic Pressure	Medium	Measuring pressure at 4 points on the forebody and 3 on the afterbody	IMU, utilizing 3 axes accelerometer, Pressure Transducers forebody (TEADS) and afterbody (COMARS)	IMU: Juno, GRAIL, MAVEN. TEADS: MSL. COMARS: Schiaparelli
Vehicle Attitude, Aerodynamic Coefficients	Medium	Measuring surface pressure, density and wind speeds at 4 forebody locations	IMU, pressure transducers (TEADS)	IMU: Juno, GRAIL, MAVEN. TEADS: MSL.

2026: FROM DESIGN TO DELIVERY



Flight Hardware Delivery Year – Integration at Lockheed Begins

- Hardware Acceptance Reviews (HAR) for DragSTR, DrAFT and COSSTA completed. DAS HAR to be held in the next months
- Delivery of flight sensors to Lockheed Martin early July
- Mid July, accept DLR DAS and then deliver to Lockheed at the end of September.
- Support sensor and DAS integration into the aeroshell.
- Get ready for LAUNCH!!



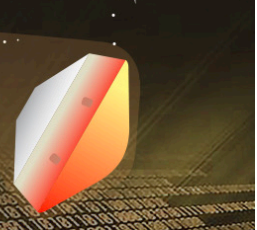


DREAM

Level 1 Science Requirements

PI Assessment L1 Science Return

-  Has been demonstrated
-  Unique application / established sensors
-  Analysis development required / established sensors

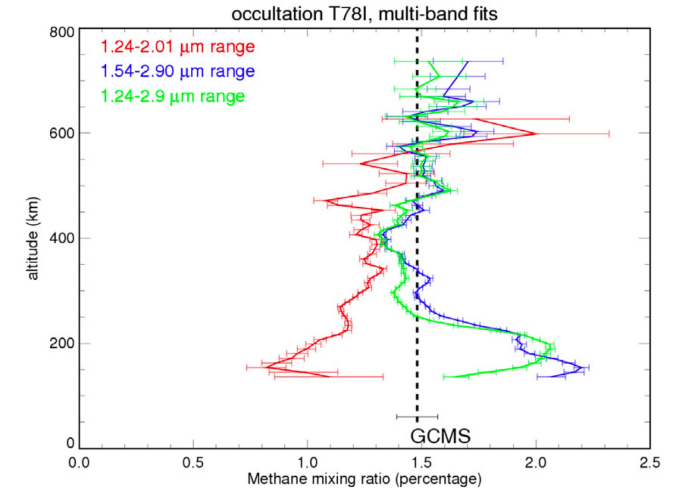


Aeroheating Environment	Forebody & aftbody aeroheating prediction	
Flow Transition	Boundary-layer transition across the heat shield	
Thermal Soak	Evaluates thermal soak effects on TPS from entry to heat shield jettison	
TPS Surface Coatings	Assesses NuSil coating influence on material response	
Methane Concentration	Estimate methane concentration during Titan entry	
Heat Flux Measurement	Measure aftbody heat flux during entry.	
Flow Separation	Identify flow separation on aftbody	

Atmospheric Density	Estimate atmospheric density	
Aerodynamic Force Coefficients	Calculate aerodynamic force coefficients	
Angle of Attack	Determine angle of attack	
Angle of Sideslip	Determine sideslip angle	
Do No Harm to Dragonfly	Do no harm to Dragonfly mission and minimal impact to ConOps	
DrEAM Data Acquisition	Acquire data from all sensors.	
Dynamic Stability Wake Pressure Coupling	Correlate aeroshell dynamics with wake pressure oscillations	

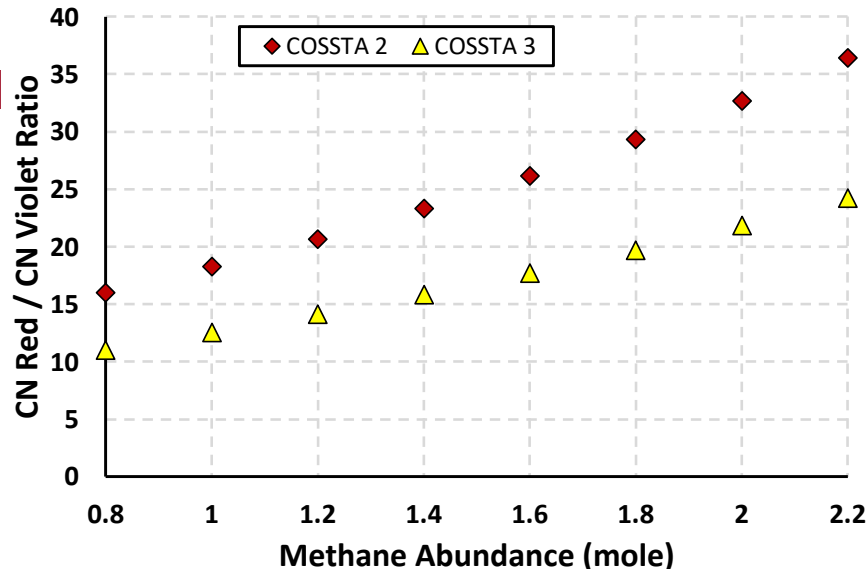
How to Infer Methane Abundance...

- Radiative heating is sensitive to the amount of CH_4
- We need the atmospheric composition to reconstruct DrEAM data
- DrEAM measurement range is for altitudes ~ 500 to 180 km
- The CH_4 uncertainty bound for upper altitudes is ~ 0.9 to 2.2% .
- DrEAM will make narrowband radiative heating measurements of CN Violet & CN Red at three backshell locations.



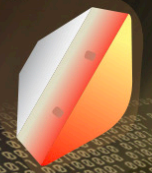
Maltagliati et al "Titan's atmosphere as observed by Cassini/VIMS solar occultations: CH_4 , CO and evidence for C_2H_6 absorption" Icarus 248 (2015)

Can we determine a non-dimensional ratio from COSSTA data that correlates with CH_4 abundance?



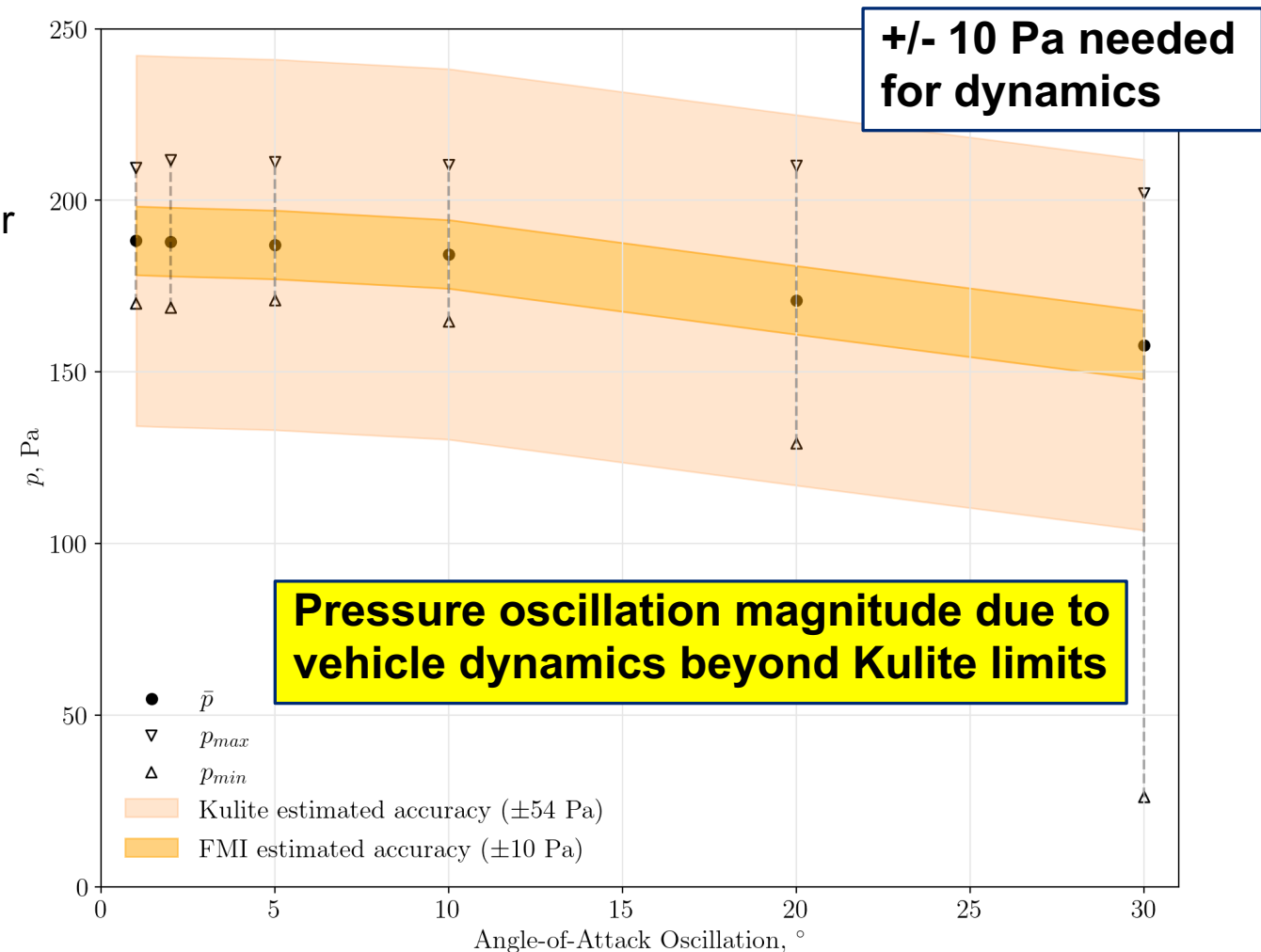
Challenge: To evaluate a quantity independent of calibration or model choice after 7 years of cruise to Titan & mitigate deposition on the sensor filters during entry.

Science Objectives: Understand Vehicle Orientation and Dynamics



- Super/Transonic instability of entry capsules is driven, in part, by hysteresis between the fore- & aftbody pressure distribution.
- DrEAM pressure data will be used to inform new models for vehicle dynamic stability.
- **Aftbody pressure sensor must be sufficiently accurate to resolve fluctuations due to angle of attack oscillations.**

Challenge: To correlate dynamic stability using relatively low resolution sampled and noisy wake pressures at one backshell point against the dynamics of the aeroshell evaluated from the DrAFT pressure transducers and the IMU accelerometers.



Representative oscillatory backshell pressures for COSSTA 2 at drogue deploy from CFD



Wake up; E-250 min

Turn to entry, spin up to 2 rpm; E-27 min

Cut thermal loop; E-22 min

MDNav to EDL Handoff (7800 km); E-10 min

Cruise Stage Separation; E-10 min

Entry Interface (1270 km); E=0

Peak heating
247 km; E+228 s

Peak deceleration
219 km; E+241 s

FMI

Droge deployment
142 km; E+274 s

Main parachute deployment
4 km; E+94 min

90 min Descent
under droge

Heatshield separation
3.6 km; E+96 min

Reconfigure EDL
thermal loop;
2.5 km; E+106 min

Lander Pose
2.3 km; E+108 min

Despin
2.3 km; E+109 min

Lidar Ground Lock
2 km; E+111 min

Lander Separation
1.2 km; E+119 min; 2.9 m/s

Transition to Powered Flight
Release + 1 s

DrEAM EDL Instrumentation for Dragonfly



COSSTA sensors:

- Beyond EDL science, characterize methane abundance in upper atmosphere

Kulite

FMI sensors:

- Capture pressure data from entry interface through droge deployment
- Coupling of wake flow and dynamic (in)stability

Kulite sensors:

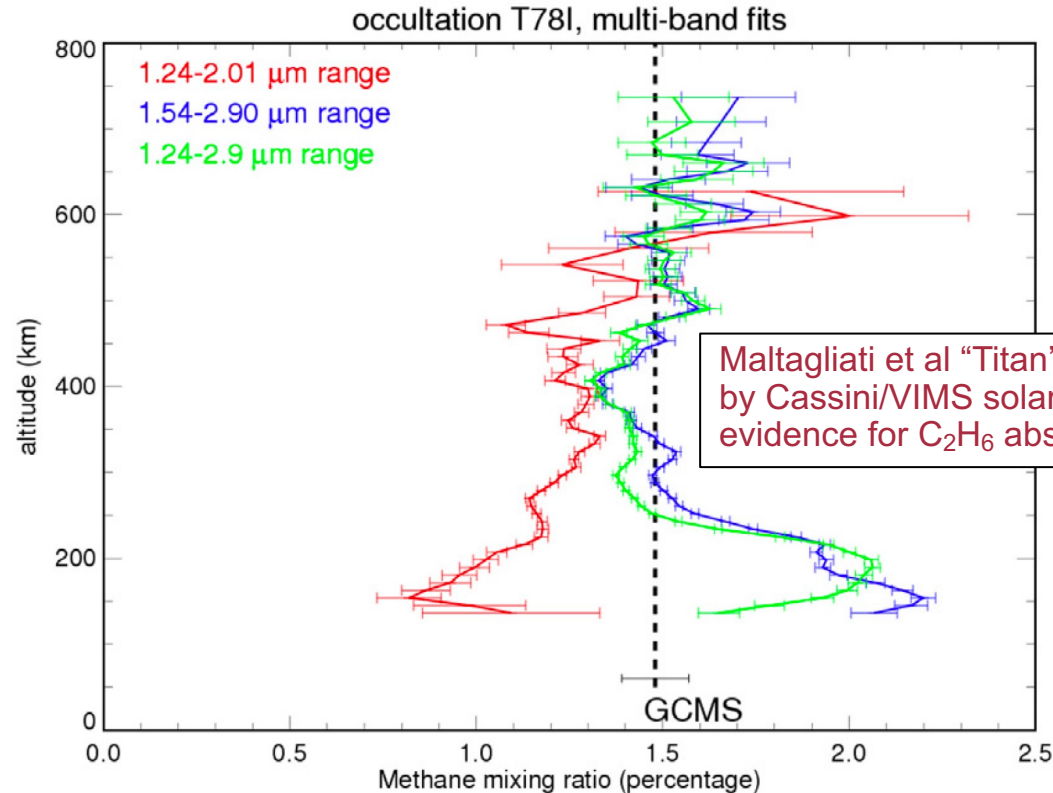
- Pressure data under droge

Dragonfly is a DrEAM drop test for dynamic stability of passive entry vehicles – currently a key risk mitigation area for Dragonfly and MSR-EES

Science Objectives: COSSTA

- Infer the abundance of methane in Titan's upper atmosphere by analyzing measurements made of CN Red and CN violet by narrowband radiometers in different flow regimes on the aftbody. (**narrowband radiometers**)
- Determine if/when flow attachment occurs on the backshell by examining any discontinuities in aftbody surface pressure measurements. (**multiple COSSTA pressure transducers**)

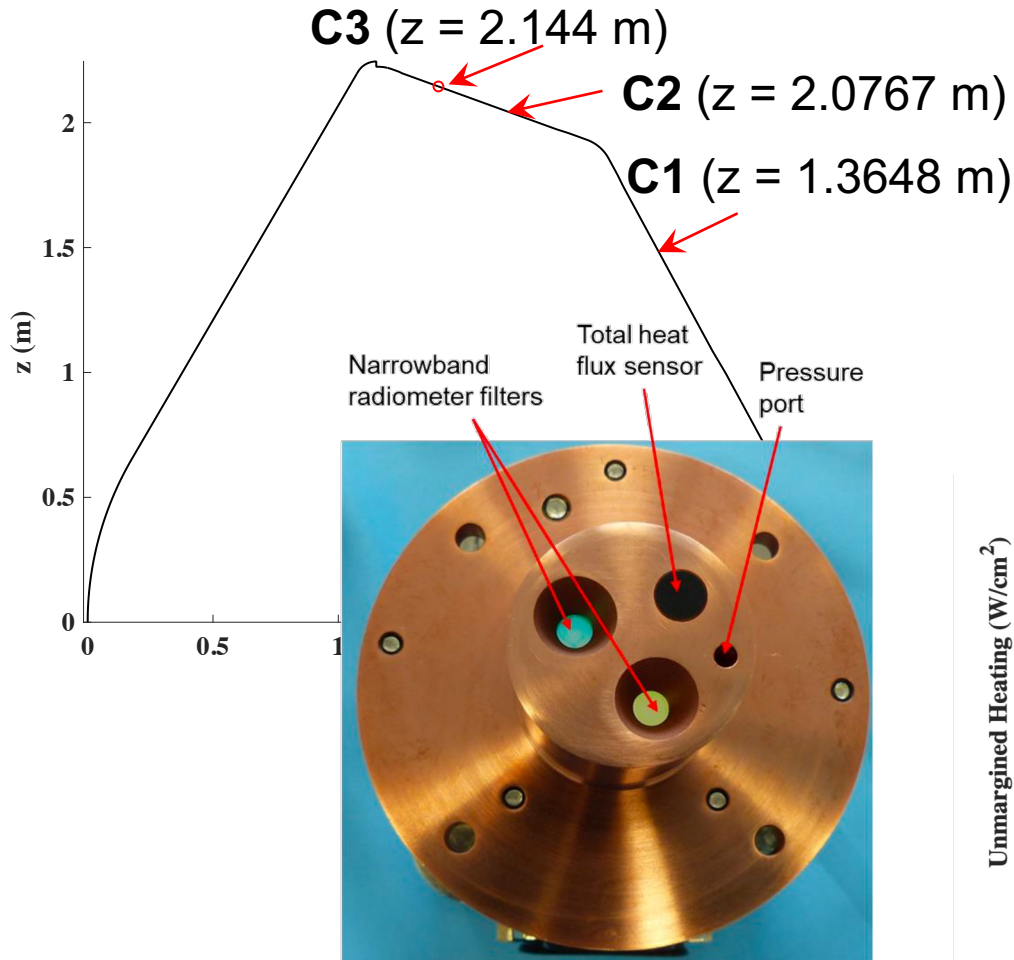
Provide critical data for DrEAM reconstruction: Freestream CH_4 and backshell flowfield topology



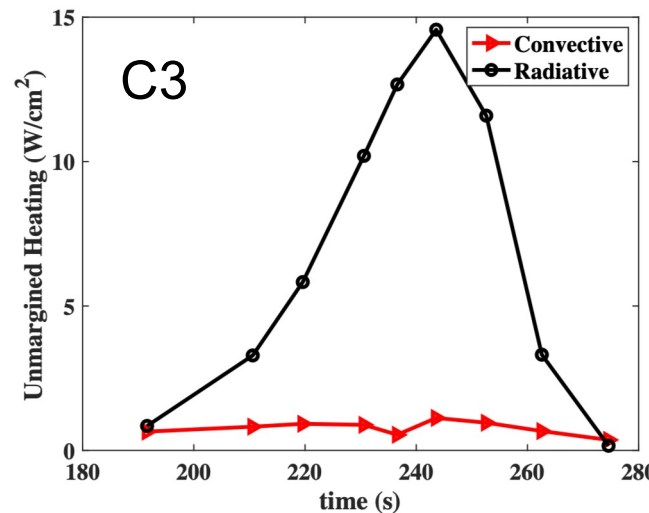
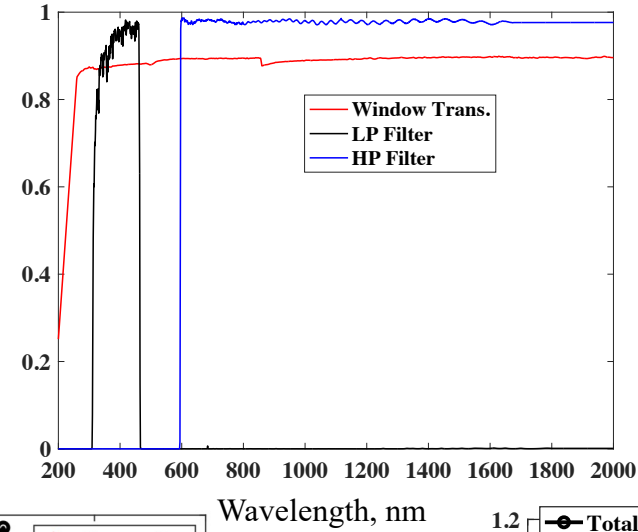
Maltagliati et al "Titan's atmosphere as observed by Cassini/VIMS solar occultations: CH_4 , CO and evidence for C_2H_6 absorption" Icarus 248 (2015)

DrEAM Radiometer Environments

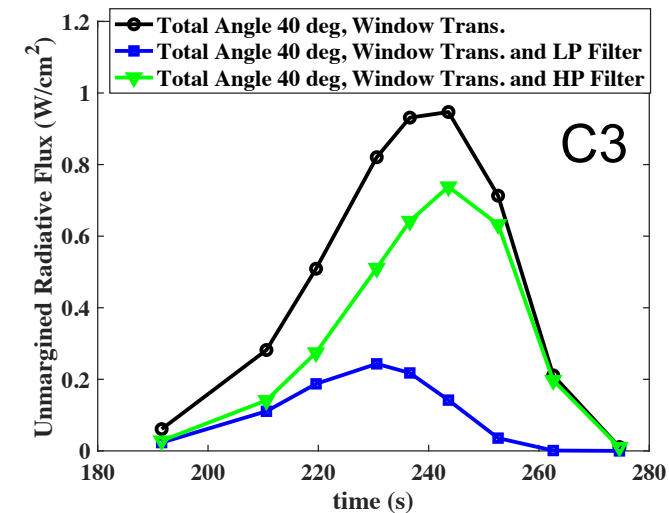
Sensor Locations



Window and Filter Transmissivities



Simulated radiative heating at sensor surface location

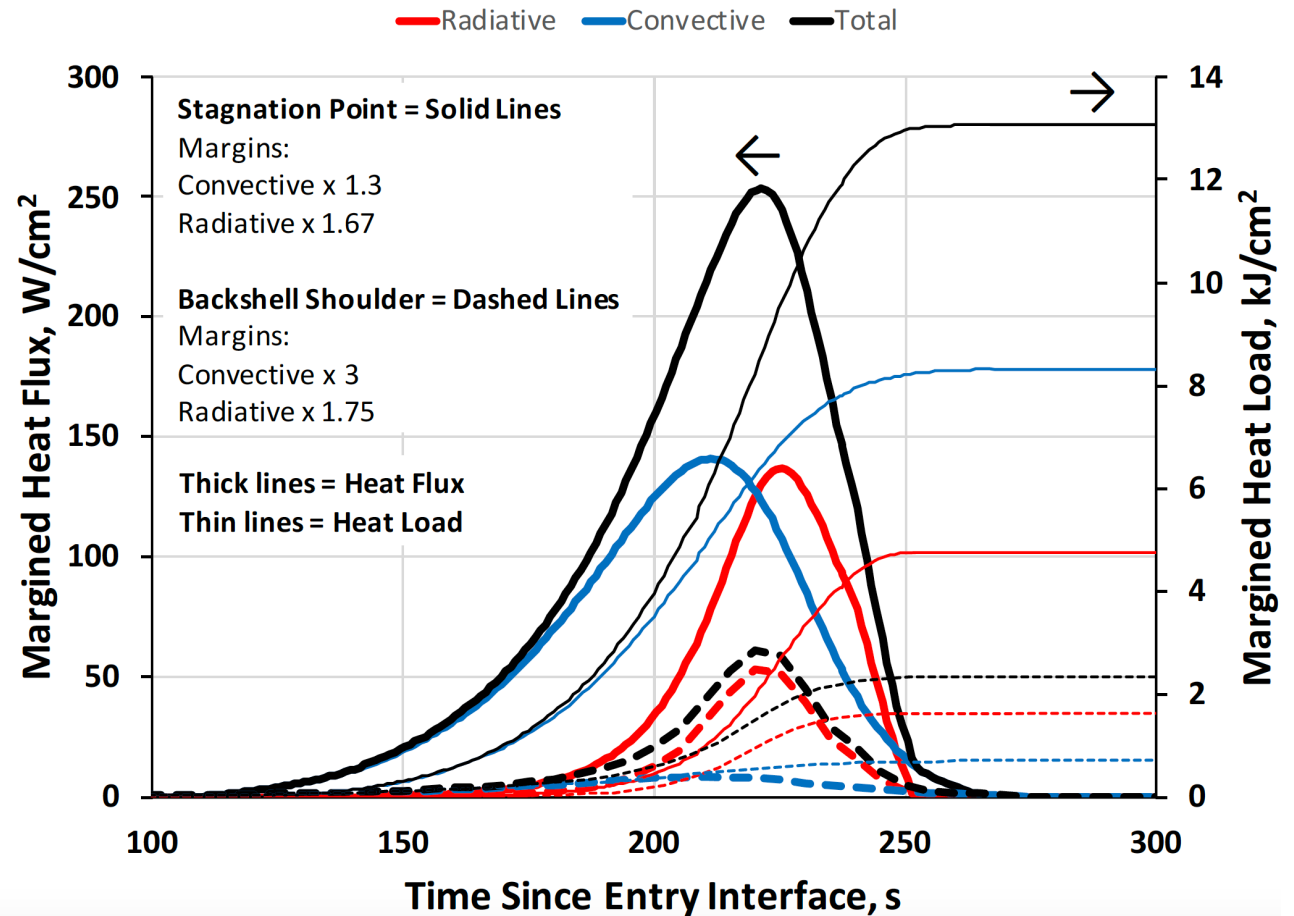


Simulated irradiance at sensing element

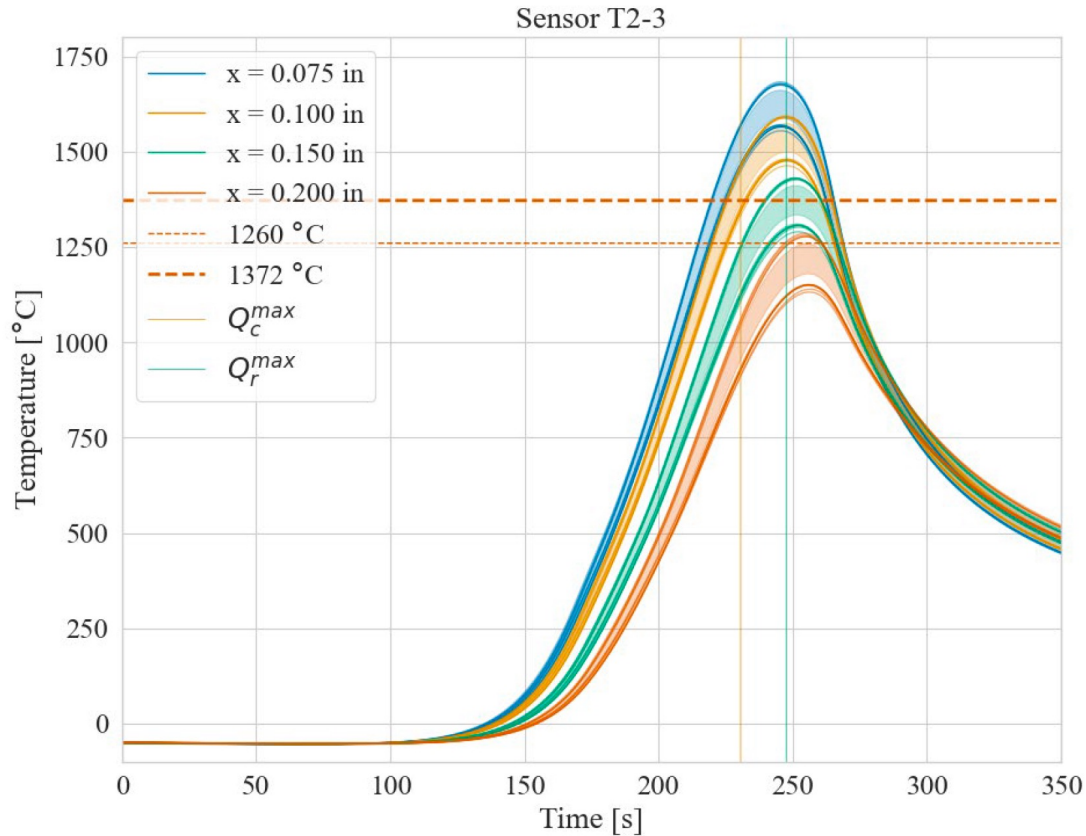
DragSTR Science Objectives: Improving Aerothermal Models

- Infer the forebody aerothermal environment across the acreage of the heatshield through inverse analysis.
(near surface TCs for heat pulse)
- Assess the heatshield material response performance in a non-oxidizing environment. (near & in-depth TCs for heat pulse)
- Assess flight impact of NuSil. (near surface TC2 & TC3)

Improve Titan aerothermal and non-oxidizing material response models



DrEAM Thermocouple Depths

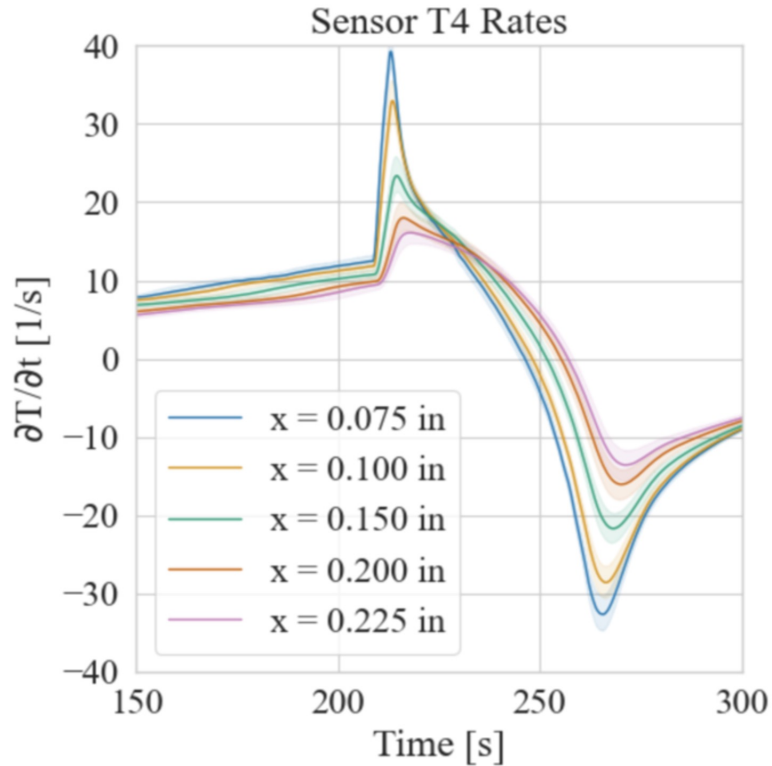


Based on the plot above 0.15" may over-temp, but a TC deeper than 0.2" will survive

- T1, T2, T3 are our aerothermal environment reconstruction TCs
- T4, T5 are focused on transition to turbulence, and we have accepted the risk that the nearest to surface TC might over-temp

Forebody TC Plug #	Depth (inches)	
T1	0.15	0.24
T2	0.15	0.24
T3	0.15	0.24
T4	0.075	0.24
T5	0.075	0.15

DrEAM Thermocouple Depths



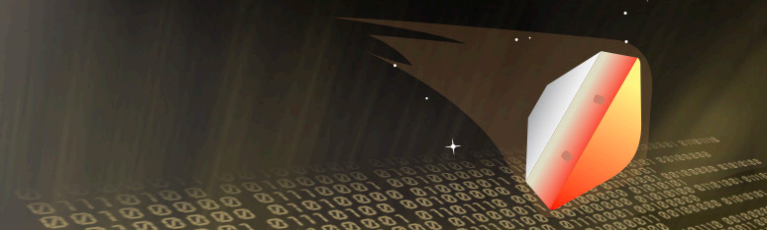
T4 & T5 TCs have a near surface depth of 0.075" to better capture a transition to turbulence

- T1, T2, T3 are our aerothermal environment reconstruction TCs
- T4, T5 are focused on transition to turbulence, and we have accepted the risk that the nearest to surface TC might over-temp

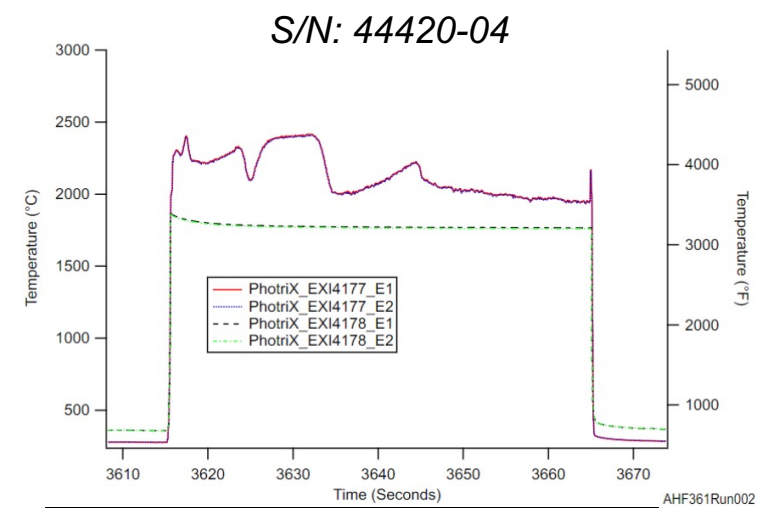
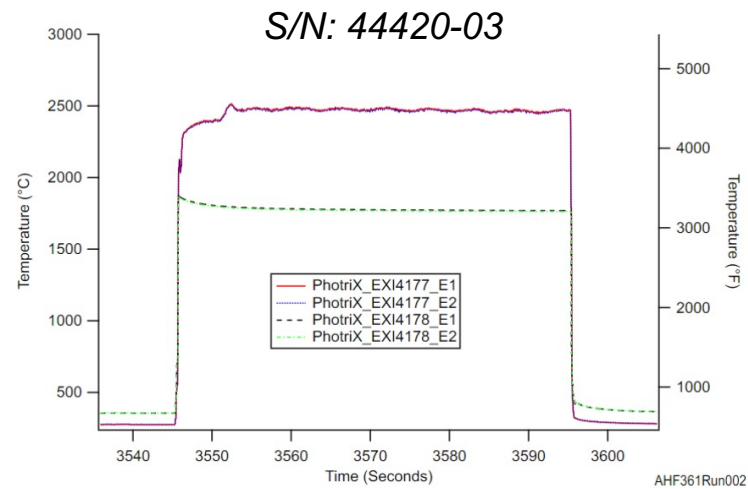
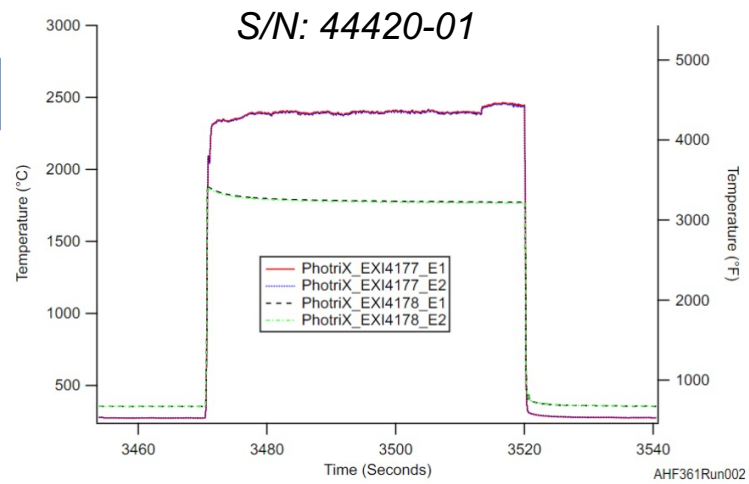
Forebody TC Plug #	Depth (inches)	
T1	0.15	0.24
T2	0.15	0.24
T3	0.15	0.24
T4	0.075	0.24
T5	0.075	0.15

Run 2: High Condition Surface Response

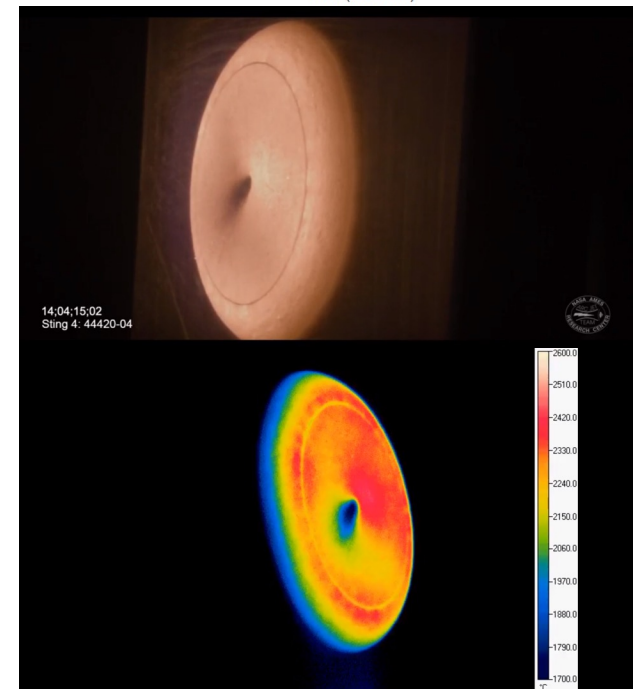
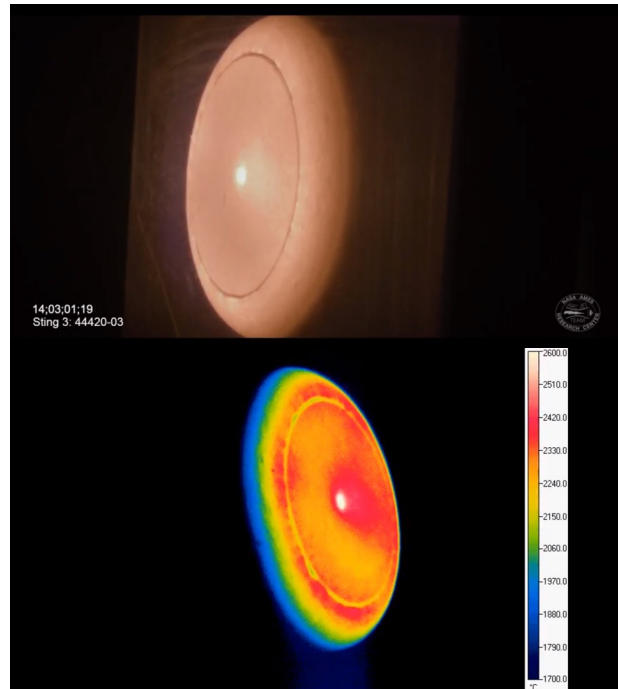
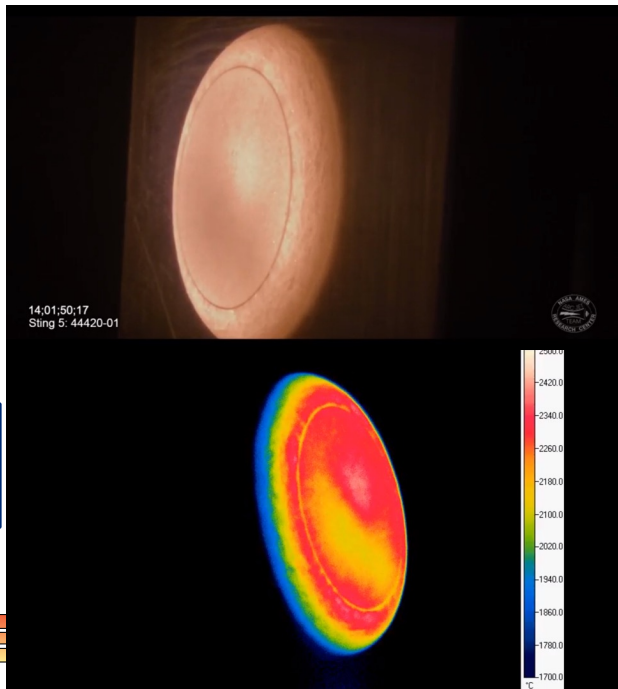
($q_{hw} \approx 300 \text{ W/cm}^2$, $p_{stag} \approx 31 \text{ kPa}$, 49 sec exposure)



T_{surf}



Video

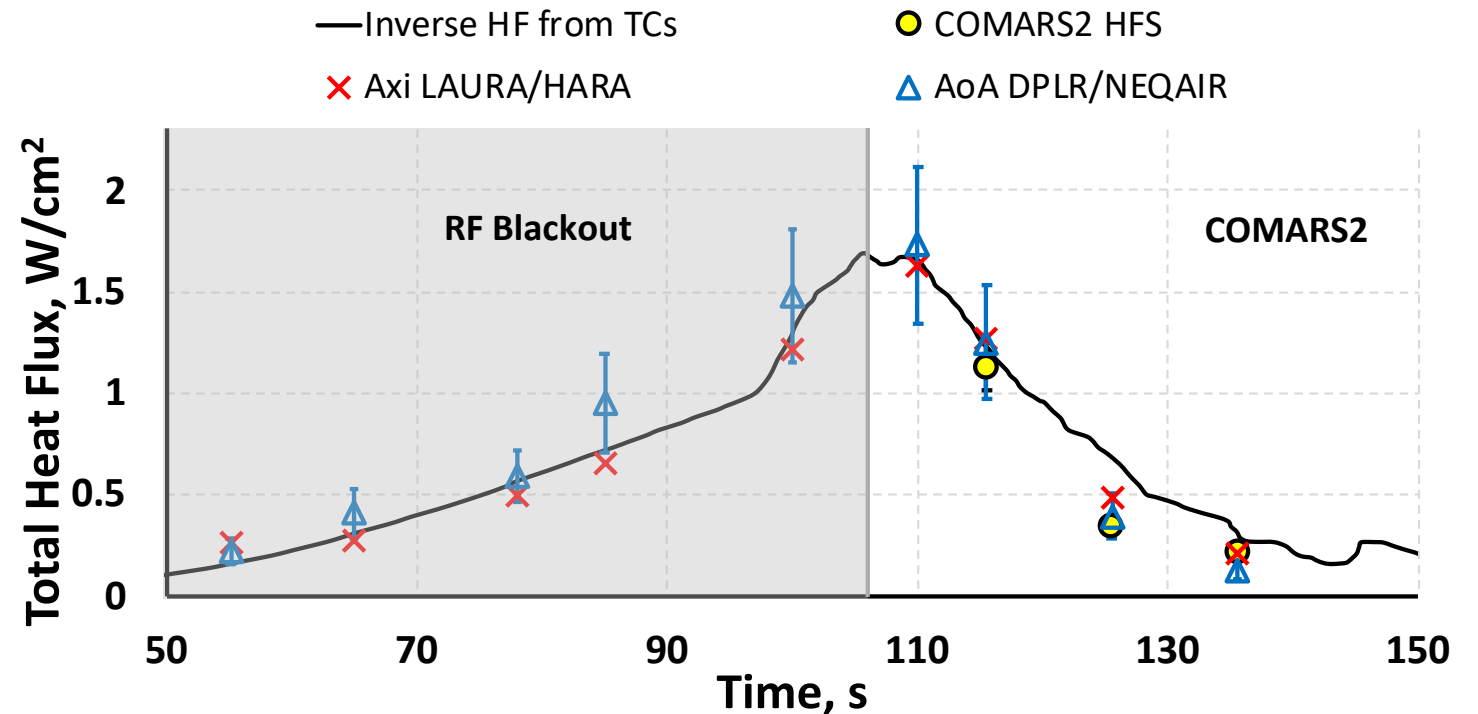


IR
Camera

Science Objectives: COSSTA / DragSTR

- Infer the aftbody aerothermal environment through the data fusion of three different measurement types: 1) near-surface and in-depth TPS temperature, 2) total heat flux and 3) radiative heat flux.
(radiometers, total heat flux)
- Quantitatively assess the contribution of CN Violet and CN Red bands to the aftbody radiative heating.
(narrowband radiometers)

**Improve Titan entry backshell
aerothermal models**



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