

LUCY



Surveying
the Diversity
of Trojans

Innovation in Adversity: Lucy's Triumph

TFAWS

Donya Douglas-Bradshaw, Lucy Development PM

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One Spacecraft, 9 Asteroids, 12 Years



Mission Description

- PI-led Mission, Dr. Hal Levison
- Category 2, Risk Class B
- 11.6 yr mission
- 1 Main Belt Asteroid Rehearsal (2025)
- 5 Trojan Encounters (9 Asteroids) (2027-2033)

Science Objectives

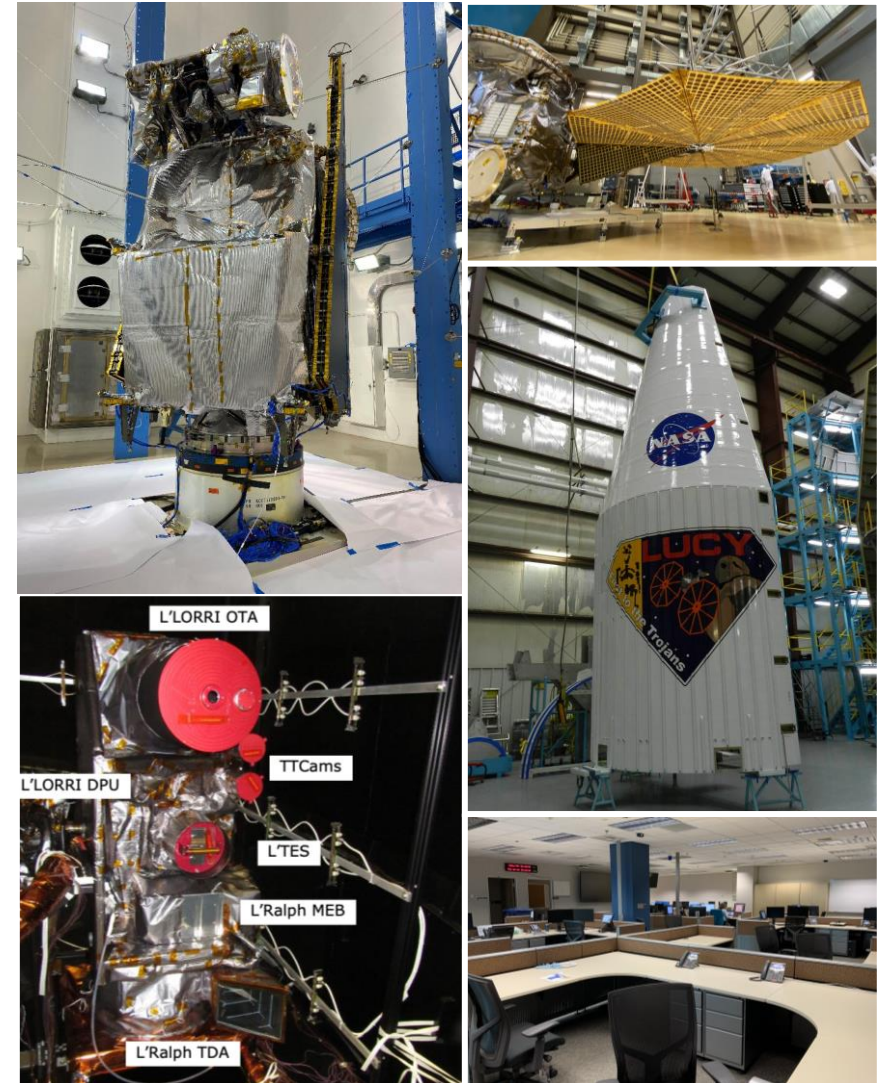
- Observations of surface geology, color/composition, interiors/bulk properties, and satellites/rings of Trojans
- Diverse Trojan targets include C-, D-, and P- spectral asteroid types

Science Suite

- L'Ralph – combined visible color imager and near infrared spectral mapper
- L'TES – thermal emissions spectrometer
- L'LORRI – high resolution panchromatic imager
- TTCam – visible terminal tracking cameras for on-board guidance and control

Launch via NASA/KSC LSP

- Launch Vehicle – ULA Atlas V 401
- Launched: October 16, 2021 @ 5:34am EST



Lucy, like the human fossil for which it is named, will revolutionize the understanding of our origins by exploring the “fossils” of our solar system.



Lucy Met Every Milestone from Proposal Through its Critical Design Review



- December 22, 2016: Selected on Discovery Program 2014 Announcement of Opportunity
- June 14, 2017 – October 30, 2018: Preliminary Design and Technology Completion Phase
- October 15 – 18, 2019: Successfully completed Mission Critical Design Review
- October 30, 2018: Agency Confirmation Review and authorization to proceed into Final Design and Fabrication
- **October 31, 2018: My first day on the job as the Deputy Project Manager**
- October 31, 2018: Started Phase C: Final Design and Fabrication
- **August 1, 2019: ~ 9 months after joining the project, I took over as the Project Manager when the incumbent retired**

But then came COVID-19...



A Time I'll Never Forget

COVID-19: Things Moved Rapidly in March 2020

March 10, 2020

"We Are Family"

I was sitting in my office with Vince Elliott, my Deputy Project Manager for resources and we were discussing what had kept Lucy on track in spite of all the challenges we were experiencing through development. After given it some thought I got up and wrote three words on my white board **"We are Family"**.

March 14, 2020

"Taking Care of Our People"

NASA moved to Stage 2 of the Agency's COVID-19 Response Framework - telework was strongly encouraged for employees who could work remotely. Given the unknown, unknowns, the PI and I met to discuss standing down for a year.

March 16, 2020

"Coalescing Around a Shared Vision"

I held a Project wide All Hands to share the Project's Go Forward Plan given the potentially limited/restricted access to work sites due to COVID-19 and to status the Project across all partner institutions.

March 24, 2020

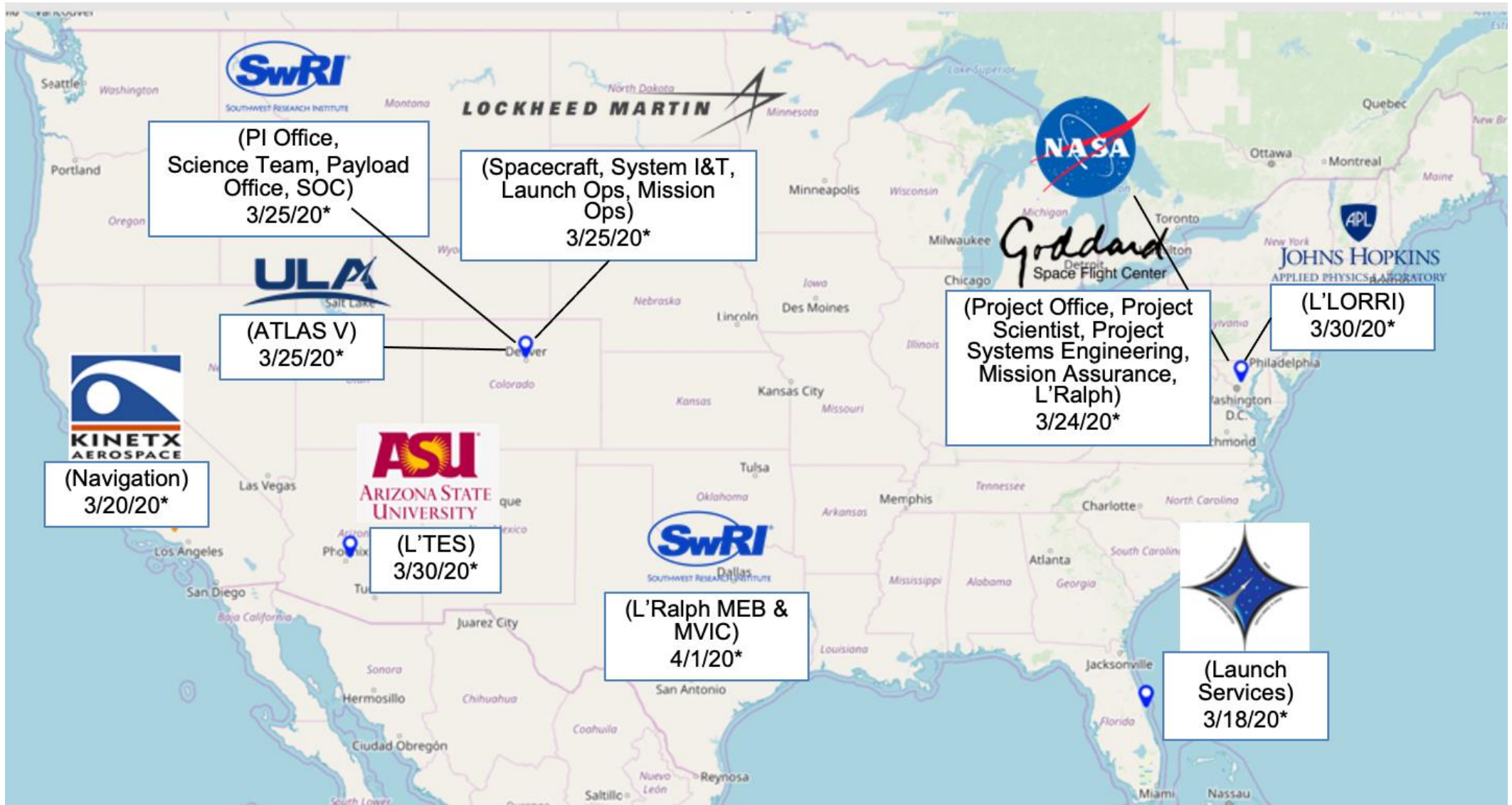
"We Grow When We Face Challenges"

Agency directed Goddard to move to Stage 4 of the Agency's COVID-19 Response Framework – Telework was mandatory for both Lucy and L'Ralph. L'Ralph had to "safe" their hardware. Travel was restricted. As I was turning off the lights and locking up the Lucy office suite, I wrote **"Lucy Strong, Welcome Back"** on the white board.

No one knew what the future held... nor did we envision that we'd never fully occupy that space ever again.



Lucy Partners: Initiation of COVID-19 Protocols



*Date when states issued stay-at-home orders or Centers transitioned to mandatory telework.



The Challenge



- **Context:** By April 1st, every Lucy partner was operating under either a state issued stay-at-home order or mandatory telework. As a result, all hardware elements experienced some losses in efficiency/ productivity and/or schedule delays. In addition, there was anxiety around the lack of understanding of the coronavirus, and the potential impact to the team.
- **Challenge:** Maintaining the health and safety of the team while delivering a spacecraft that met the science objectives within the cost and schedule constraints, with acceptable risks.

Eric Hoffer said that a “the leader has to be practical, and a realist yet must talk the language of the visionary and the idealist.”



The Strategy

- First Things First: We established a Project wide COVID-19 protocols and response framework that was consistent with the Agency's framework and CDC guidelines.
- Project aggressively spent reserves to mitigate COVID-19 impacts and meet the planetary launch window.
- Utilized a very proactive “what-if” approach to assess “risk exposure”, identify trade space, and to develop work around plans for a number of scenarios, e.g. work stoppage due to COVID, late hardware delivery, etc.
- In June 2020 the Project implemented the FAST (Feasible ATLO Shortened Timeline) Plan.
- We could not lose site of the “human factor”. The Project's success thus far, had hinged on the social/relationship equity built up over the years. So, the Project made a concerted effort to maintain the sense of team spirit.

Dedication, Innovation, Inspiration



We Found Inspiration in a Number of Things, Including a Pineapple

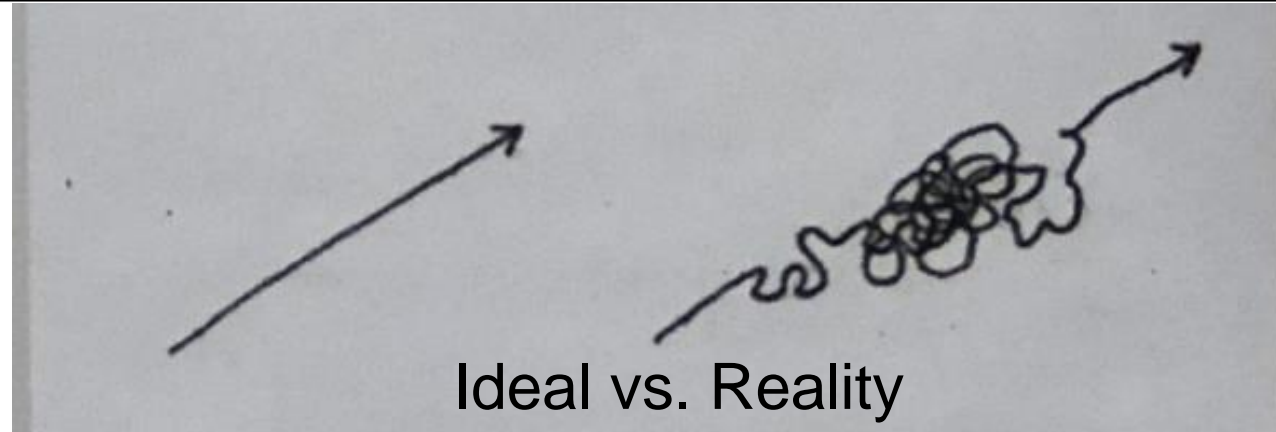


- **Teamwork:** The fruit of the pineapple plant is actually 200-plus flowers coming together to form a single fruit.
- **Endurance and Perseverance:** It can take up to three years for a pineapple fruit to grow ready for harvest. Like success, it doesn't happen overnight. Time, patience, and hard work are all required to get results.
- **Versatility:** The pineapple is not a one trick pony. It can be used to make wine, tenderize meat, serve as a fancy cup for your fruity, poolside drink, or a very non-traditional jack-o-lantern. Lesson here: look beyond the obvious in your teammates, tools, and ideas.

Common Vision, Common Goal



We Had a Plan and We Had the Team



We knew that getting to launch was going to be hard, but we had a plan; more importantly, we knew we had the team to get us there.

Other Issues Threatened Launch



Open: Late L'TES Delivery



Problem/Issue	Programmatic Impact	Action	Status
R L'TES Late Delivery To maintain schedule, prior to the instrument vbe test, the L'TES team performed an accelerated staking cure at elevated temperature (at vacuum, non-operational). During the post-cure functional, a degradation in the Infrared Instrument Response Function (IRF) and Fringe (laser) performance was observed, indicative of optical tilt in the system th IRF. Lase impacted changes. additional ongoing to cause anc	L'TES October 8, 2020 delivery is in jeopardy, which would impact ATLO.	1. Identify sources of the shift and necessary workarounds. 1A. Perform elevated thermal cycle (completed) 1B. Perform workmanship-level vibration test (completed) 1C. Perform cold performance testing (completed) 1D. Characterize spare Beam Splitter to assess its performance (ongoing) 2. Establish root cause and implement rework (ongoing)	9/10/20 <ul style="list-style-type: none"> L'TES continues to operate under a FRB to e the tilt in the infrared data stream and the an Laser Metrology system (these are two sepa issues). A new lens design for the Laser Metrology S has been completed and breadboarded and : FM lens is on order and expected to arrive st ASU is assessing the tilt issue is by testing th Rex TES (OTES) spare flight module and th spare flight beam splitter assembly. ASU has established a schedule and go forw with a decision point around 9/24. The new s accounts for the re-work, restores Funded St



Open Issue: PMD Weld Failure



Problem/Issue	Programmatic Impact	Action	Status
Y Propulsion Management Device Weld Failure During welding of the perforated plate/screen assembly to the inlet assembly the perforated plate/screen became	The manufacturing issues and failed propulsion management device weld have resulted in a two month delay to the propulsion subsystem. If the weld effort is unsuccessful and requires a new design build, the LRD could be jeopardized.	1. Fabricate test parts for alternate design and complete demo welds (complete) 2. Onboard additional weld technicians and engineers (complete) 3. Conduct independent assessment of PMD/Tank verification and test plan (ecd 3/30/20)	3/18/20 <ul style="list-style-type: none"> LM completed first of six perforated plates needed for flight build, machining running on or slightly ahead of plan. 3/2/20 <ul style="list-style-type: none"> Efforts at LM over the month of February have identified a design update to the tank propellant management device sump plates which is producible, and they are now moving forward with production of this new design. The PMDs for all three tanks are now projected to be complete by the end of April 2020. Propulsion remains on track for the delivery in mid-October

Open Issue: Solar Array Schedule Erosion



and nk.

Problem/Issue	Programmatic Impact	Action	Status
Y Lucy Solar Array Delivery Date Schedule Erosion Lucy Solar Array baseline plan is to complete development, environmental test and deliver to the S/C in August 2020. The S/C ATLO need date for the Arrays is December 2020. The forecast delivery date has experienced significant erosion and continues to slip.	If the solar arrays are not delivered by the ATLO need date, the Lucy environmental test program will need to be reordered and replanned, resulting in cost & schedule impacts	<ul style="list-style-type: none"> Identify and evaluate additional schedule risk mitigation options (ecd 10/15/19) Complete solar array coupon qualification (mid-Oct) Start laying down flight CIGs (ecd 10/18/19) Complete contract action with LM to finalize remainder of solar array subcontract scope & cost (ecd 10/30/19) Implement selected options (ecd 11/30/19) Complete action to put S/A Tvac test facility on-contract and initiate test planning (11/30/19) 	<ul style="list-style-type: none"> Solar array development has consumed all of their schedule margin and almost all of the 4 months of slack to the ATLO need date. Both NGIS and SolAero have been tasked to develop schedule risk mitigation options Completed solar cell bonding pathfinder activity and first set of 6 gorlets will be delivered to SolAero this week. S/A qual coupon failures have been brought to FRB – investigation and corrective actions are in-work NGIS has added a GSE Lead to the team LM has instituted Monthly Management Reviews with NGIS. Lucy PM and DPI have started attending.



Open: Hydrazine Manufacturing Change



Problem/Issue	Programmatic Impact	Action	Status
Y Hydrazine Manufacturing Process Change Impact to Heritage Thruster Qualification Summer 2018 change in the hydrazine manufacturing process from the heritage "Raschig" process to the "Ketazine" process by the DLA-managed sole supplier of hydrazine allows trace carbon-based contaminants that potentially invalidate heritage (ACS/TCM) thruster qualification.	Additional life and/or material compatibility testing may be required to supplement the existing qualification baseline for the ACS (MR-103J) and/or TCM (MR-106L) thrusters in order to take into account the process change to Ketazine. This would lead to cost and possibly schedule impacts.	1. Acquire flight quantity of hydrazine manufactured by heritage Raschig process. 2. Review test results of heritage batch. (ecd 4/15) 3. Monitor ongoing ETD/597 efforts (in cooperation with NESG and USAF/ Aerospace) to understand and mitigate technical risk associated with new process (issue likely impacts all Projects with monopropellant thrusters). 4. Work with Senior Management on Process for Setting Priorities between projects for existing store of fuel	3/18/20 <ul style="list-style-type: none"> HQ has been made aware of Lucy's concern/need. SMD is setting the priority for "old" hydrazine and my understanding is that Lucy is 3rd on the list. There should be enough of the Raschig hydrazine to meet all 3 mission needs. However, we have been made aware that other programs are lobbying as well. 2/28/20 <ul style="list-style-type: none"> Half of the WSTF Lonza/Raschig HPH supply has been inspected at KSC to-date with generally positive results. Minor issues with bulk particulate can be mitigated by filtering. Remaining propellant should be tested by 3/6. GSFC Propulsion working with the Lucy Project as well as in an intragovernmental effort (KSC, WSTF, MSFC, NESG, USAF/Aerospace) to characterize technical risk and identify risk mitigation. GSFC Propulsion coordinating with LM Propulsion who are conducting their own internal fleet assessment. New-process Lonza/Ketazine hydrazine has flown on at least 4 US Government and 1 Commercial mission since mid-2018. Similar process (different vendor) GHC/Ketazine HPH has flown on multiple orbital vehicles including those using TCM (MR-106L) thruster.

But we adjusted and replanned and replanned again....



The Road to Launch – ATLO Started a Week Early



April 24, 2023



The Road to Launch

Environmental Test Campaign Ran Like Clockwork

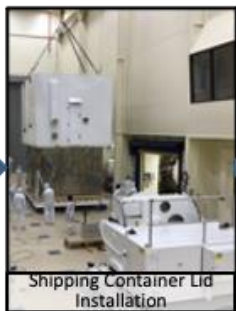
February 2021



Lift to Horizontal Transport Frame



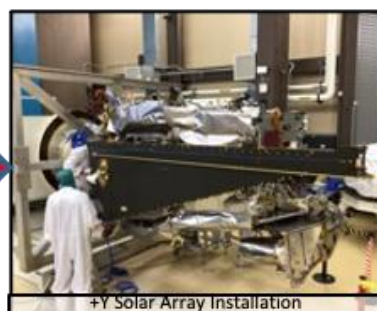
Installation on Shipping Container Base



Shipping Container Lid Installation



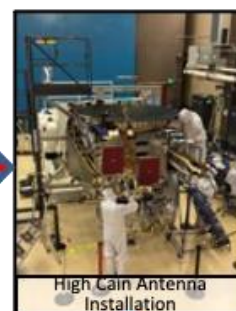
Arrival at RAL



+Y Solar Array Installation



-Y Solar Array Installation



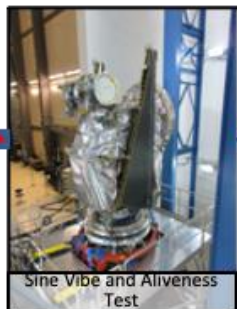
High Gain Antenna Installation



EMI/EMC, Self-Compatibility and Plugs Out



Solar Arrays Removed



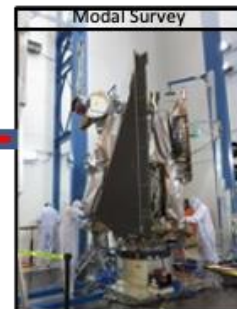
Sine Vibe and Aliveness Test



+Y Solar Array Deployment, Unfurl, Illumination, and Refurl



-Y Solar Array Deployment



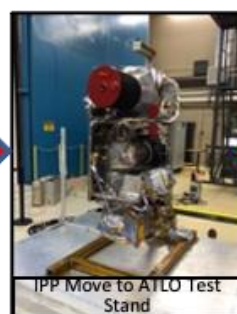
Modal Survey



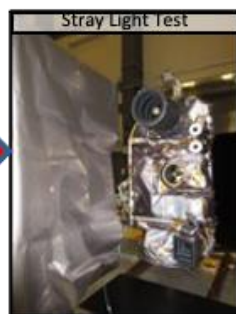
Matchmate and Clamp Band Shock



IPP Deployment #2, with Jitter Test



IPP Move to ATLO Test Stand



Stray Light Test



Spacecraft and IPP Configured for Thermal Vacuum/Thermal Balance



Solar Reflector Installed



Chamber Closeout and Pumpdown



Spacecraft Lifted out of Ivac Chamber

June 2021

The Project didn't have to compromise the ground test campaign.



The Road to Launch: Launch Operations



Spacecraft Encapsulation



Launch Vehicle on Stand



Wet Dress Rehearsal



Launch Vehicle Mate



Roll to Pad



The spacecraft shipped to the launch site and launch operations proceeded as planned.



The Road to Launch: Begins and Ends With a Great Team!



April 24, 2023

GSFC Road to Mission Success



We Accomplished What We Set Out to Do



Lucy Launched on Day 1 Opportunity 1 of its 23 Day Planetary Launch Period on 16 October 2021 at 5:34 AM EDT/9:34 AM UTC!



Main Takeaways



- FAST/FAST-ER came at a price – we pushed hard for 10.5 months under very taxing circumstances. As time progressed, the team brittleness became apparent.
 - **This would not have been sustainable under normal circumstances.**
- Lucy was successful in navigating COVID and launching on time for a number of reasons:
 - We balanced time, cost, and performance, with risk as the discriminator.
 - Risk management was continuous. We developed mitigation strategies with offramps.
 - Schedule **was** king. Every decision took into account the potential schedule impact.
 - We had healthy cost reserves, which were used to buy surge support and time.
 - We were single-minded in our vision, to get to launch and have a successful mission – decisions were made collectively (meaning all trade space was put on the table).



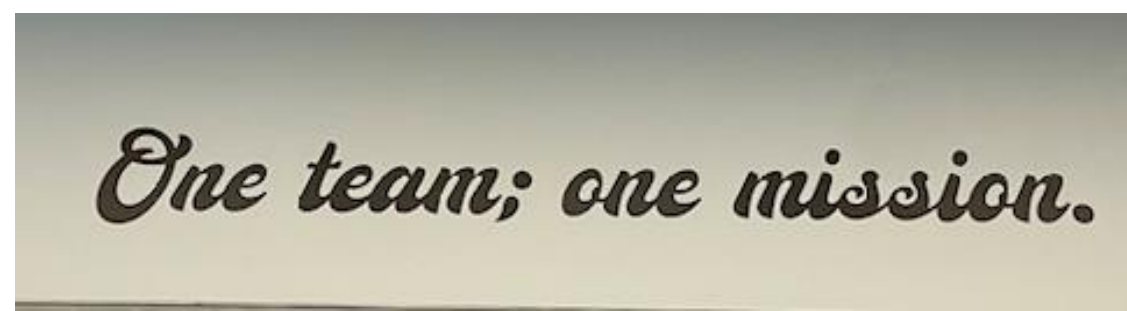
Main Takeaways (cont.)

- We maintained a people first, mission always mindset.
- We looked beyond the obvious in each other, our tools/assets, and ideas.
- We worked hard and played harder - together.
- We held each other accountable.
- We embodied the characteristics of family...openness, grace, appreciation, interest in each other and our lives. We took care of each other. We stepped in to help each other, filling in the gaps as needed.
- It was important for the leadership team (PI, PM, DPMs, Project Scientist) to show that we were in the arena too.
- The PI and PM established a familial, inclusive, teaming/partnering culture from the beginning of the project. One badge. One team. One tribe.

We demonstrated that we were indeed, Lucy Strong!



Final Thought: You are Critically Important to Your Teams Success



Your vibe attracts your tribe, sets the culture, and motivates your teams