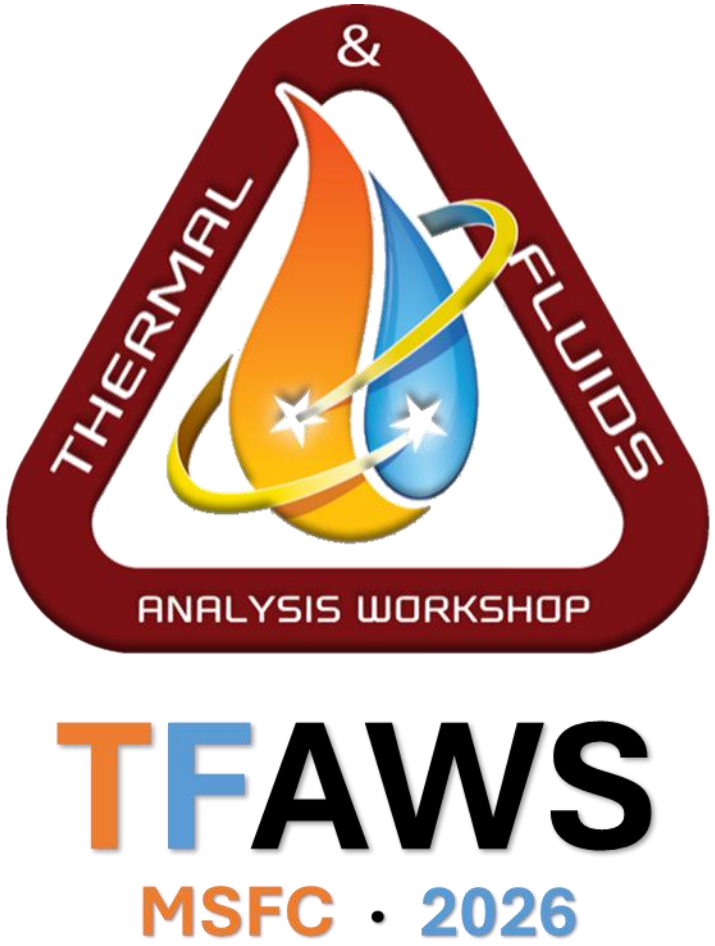


SCIFLI Artemis II Reentry Airborne Operations

Arianna Haven, AMA. Inc.
Robert Conn, AMA. Inc.

Scientifically Calibrated In-Flight Imagery Team
NASA Langley Research Center

Presented By Arianna Haven

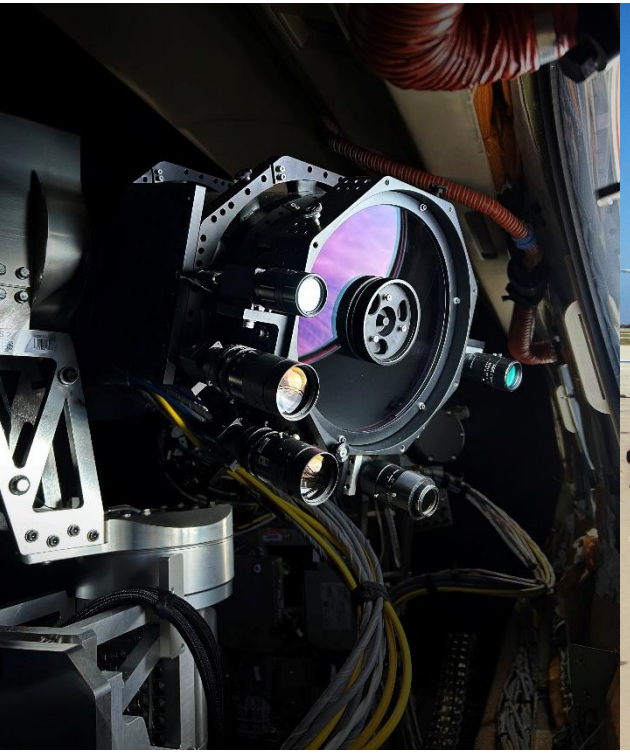
Thermal & Fluids Analysis Workshop
TFAWS 2026
August 31 – September 4, 2026
NASA Marshall Space Flight Center
Huntsville, AL

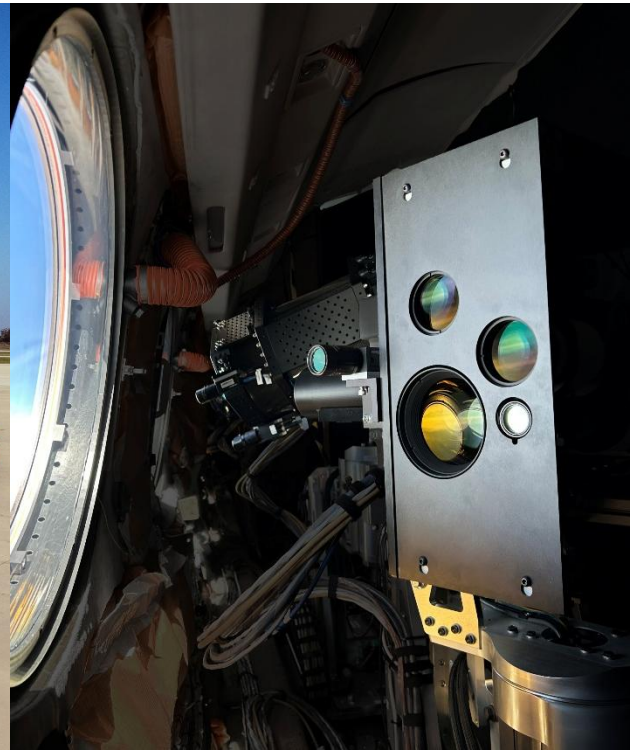
SCIFLI's Role in Artemis II Reentry

- During Artemis II Orion Reentry, SCIFLI successfully collected multispectral engineering imagery for Thermal Protection System (TPS) and Landing and Recovery System (LRS) performance verification with comprehensive coverage of from Entry Interface through Splashdown.
- A large, multi-disciplinary team collaborated to make the mission observation successful:
  - MARS Scientific → MIDAS gimbals & imaging payloads
  - OKSI → SAMI imaging payload support
  - ATA Inc. → Sensor calibration and radiometric modeling
  - NASA JSC Flight Operations → G-V, WB-57
  - NASA Armstrong Flight Operations → G-III
  - US Navy VX-30 Test Squadron → P-3
  - Missile Defense Agency HALO → G550
  - US Air Force RTB → NT-43A
  - WESCAM → Cessna Caravan
  - And *MANY* others…

Key Topics

Aircraft Selection → Aircraft Placement → Aircraft Coordination → Mission Day Execution





Aircraft Selection

1. Define imaging objectives
2. Define number of aircraft required
3. Match aircraft to objectives

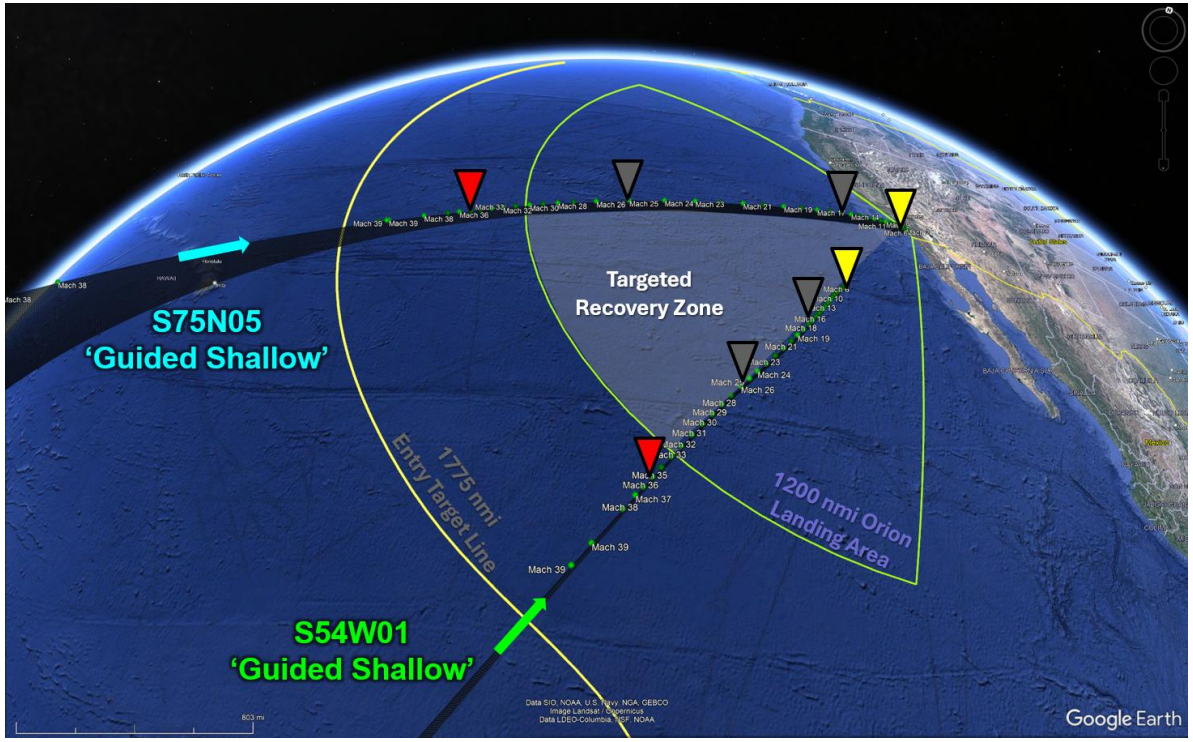
Before selecting aircraft to participate in a mission, well-defined imaging objectives are needed.

The following imaging objectives were developed between SCIFLI and the Orion Team:

Peak Heating
- Long range
- Temperature retrieval
- Maximum optical performance

Parachute Deployment
- Rapid Deployment
- MWIR tracking at night
- TPS and parachute imaging

Char Loss
- Long range
- Maximum debris detectability
- Maximum optical performance
- **Spectroscopy**



Number of Aircraft

1. Define imaging objectives
2. Define number of aircraft required
3. Match aircraft to objectives

Preliminary Trade Study (February 2025)

- Single aircraft solution (Gulfstream at peak heating) → Did not provide sufficient down-range coverage of desired TPS events
- Added second aircraft in recovery zone (WB-57) to analyze combined coverage → Did not provide sufficient resolution or coverage of mid-range TPS events
  - WB-57 – Best possible IR spatial resolution at FBC chute deployment
  - Gulfstream – Best spatially resolved coverage from recovery zone
- Three-aircraft solution (two Gulfstreams, one WB-57) → Introduced longer duration of time with line-of-site to crew module heatshield

Follow-up Studies (March – August 2025)

- Optimized 2-, 3-, and 4-aircraft imaging CONOPS based on Orion-driven TPS & LRS objectives:
  - Peak heating: Spatial resolution optimized
  - Peak char loss (Char-1): Best spatial resolution with horizon-to-horizon imagery
  - Late char loss (Char-2): Best spatial resolution with horizon-to-horizon imagery
  - FBC Jettison & Parachutes: Best MWIR spatial resolution with horizon through chute imagery

Conclusion: Four aircraft are needed to meet all TPS & LRS objectives simultaneously

Nominal Aircraft Selection

1. Define imaging objectives → 2. Define number of aircraft required → 3. Match aircraft to objectives

Preliminary Mission Design Solution (Baselined at PMR, September 2025)

Aircraft 1: Peak Heating	Aircraft 2: Char-1	Aircraft 3: Char-2	Aircraft 4: Parachutes
			
Gulfstream V ✓ Airframe meets range and loiter requirements ✓ Hosts payloads that meet imaging requirements ✓ Live streaming capability	**P-3 Orion** ✓ Airframe meets range and loiter requirements ✓ Hosts payloads that meet imaging requirements	**Gulfstream III** ✓ Airframe meets range and loiter requirements ✓ Hosts payloads that meet imaging requirements	**WB-57** ✓ Airframe meets range and loiter requirements ✓ Hosts payloads that meet imaging requirements ✓ Live streaming capability

- Preliminary aircraft selection is based on available assets within the agency and DoD partners that we've used for previous imaging missions.
- Then they are assigned to specific mission imaging goals based upon aircraft range, payloads, and live streaming capabilities, as necessary.

Aircraft Integration

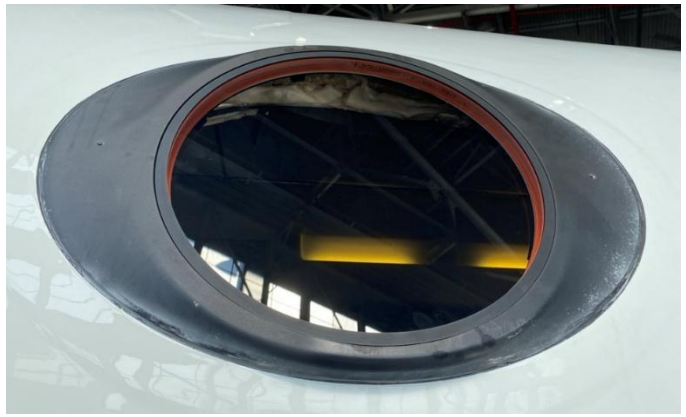
- NASA Gulfstream III and V required 2+ weeks for hardware integration, pre-flight calibration and test flights prior to mission deployment.
- WB-57 & P-3 are pre-integrated systems.

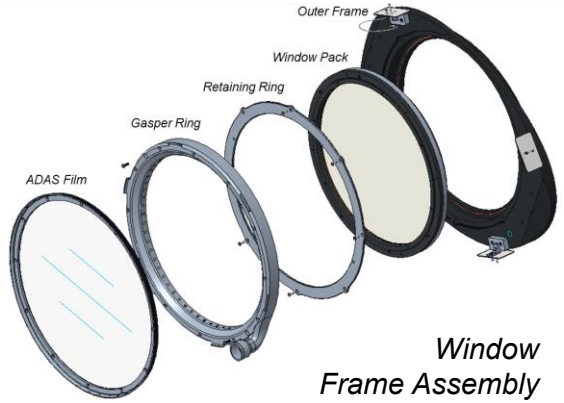
Cases of Equipment in the Hangar at Ellington Field Ready to be Integrated

Payloads Integrated on the G-V (left) and G-III (right)

SCIFLI Optical Windows

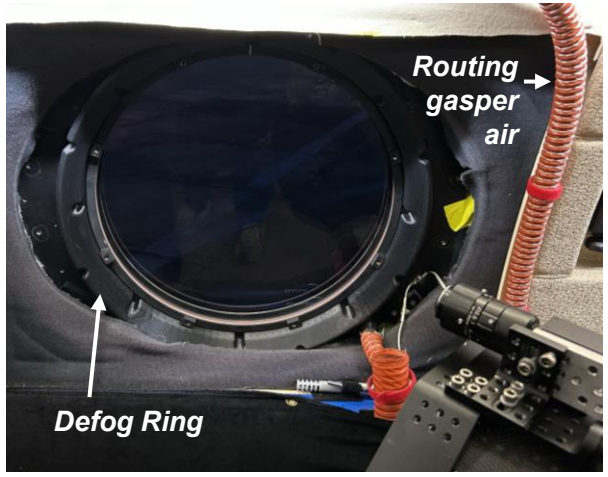
Substrates	• Qty(1) C-plane Sapphire window with anti-reflecting coating ➢ UV, VIS, NIR, SWIR, MWIR ➢ 0.75” thick • Qty(6) uncoated Corning 7890 Fused Silica windows ➢ UV, VIS, NIR, SWIR ➢ 1.30” thick
Diameter	17 inches (16.4 inches clear aperture)
Flight History	Airframes: G-III, G-IV, G-V Missions: HORIS (Sept 2023), Starship 7 Reentry (Jan 2025), ECCO-2 Mission (June 2025), Artemis II (April 2025)





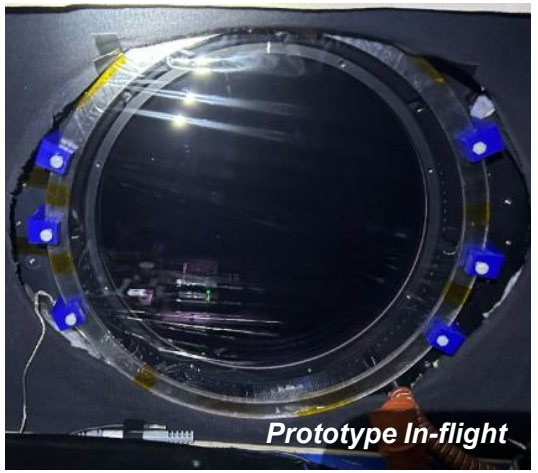
Window Frame Assembly

Thermal Problem Solving with Windows: Anti-Icing Dry Air System (ADAS)

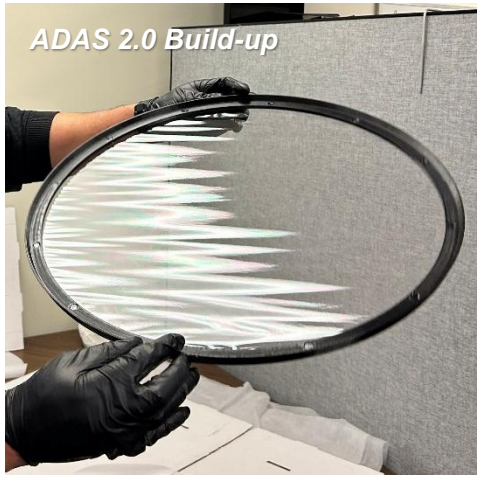


SCIFLI optical windows use a defog system that routes gasper air through a 3D-printred defog ring around the windowpane.

The gasper defog system worked for the Fused Silica but couldn’t overcome Sapphire’s high thermal conductivity, even with heated air.



The rapidly developed ADAS prototype kept the dry gasper air against the window, effectively preventing humid cabin air from freezing on the inside surface.



Since then, the ADAS has continued to evolve in form, and its defogging performance has remained consistently effective.

WB-57 Mishap

DEC

17

17DEC2025: SCIFLI Artemis II Reentry CMR

The NASA WB-57 was baselined to provide Launch and Landing & Recovery (LRS) imaging support during Artemis II during LP-17

JAN

27

27JAN2026: **WB-57 has a gear-up landing at Ellington field**

- Less than two weeks before the target launch date, the WB was deemed unairworthy to support the SCIFLI Artemis II Orion Reentry Observation.
- The backup WB-57 aircraft was in heavy maintenance and was not going to be available for flight support prior to March 2026.

FEB

6

6FEB2026: targeted first launch attempt in LP-17

NASA 927 gear-up landing at Ellington Field (EFD)

Source: KHOU News, 'NASA plane makes belly landing at Ellington Field,' khou.com."

Additional Aircraft

FEB 2 — **2FEB2026**: Artemis II Launch slipped to LP-18 (NET 6MAR2026)

FEB 2 / FEB 21 — After the WB-57 mishap, rapid trade studies were conducted to find a replacement aircraft. Three additional aircraft were added to the mission for LP-18 and future LPs as backfill and contingency (see right).

FEB 21 — **21FEB2026**: Artemis II Launch slipped to LP-19 (NET 1APR2026)

MAR 17 — **17MAR2026**: Backup WB-57 (NASA 926) comes out of maintenance and is available to support Artemis II.

MAR 28 — **28MAR2026**: Aircraft forward deploy to FL or CA for Launch and Reentry Ops

APR 1 — **1APR2026**: New targeted launch attempt in LP-19

Results: 7 total aircraft supported by SCIFLI for Artemis II Reentry Ops

USAF NT-43A
Incorporated into Launch and Reentry ops to meet Agency objectives

MDA HALO G-550
Added as a contingency aircraft for Reentry

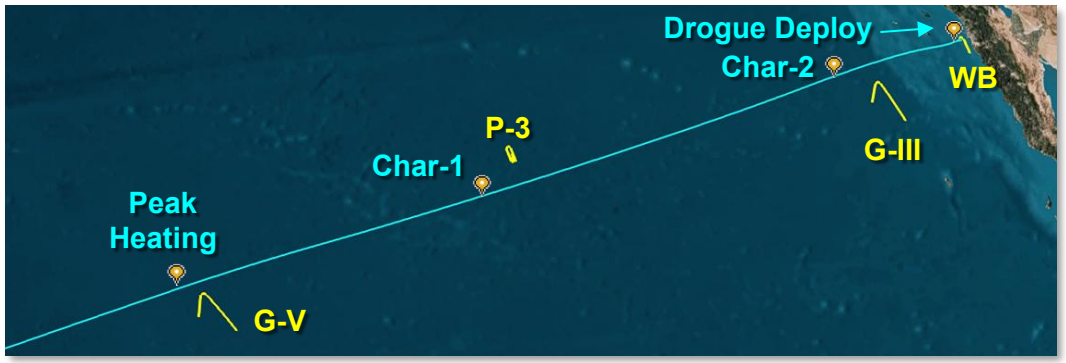
WESCAM Cessna Caravan
Added under “monitoring” status for Launch and Reentry

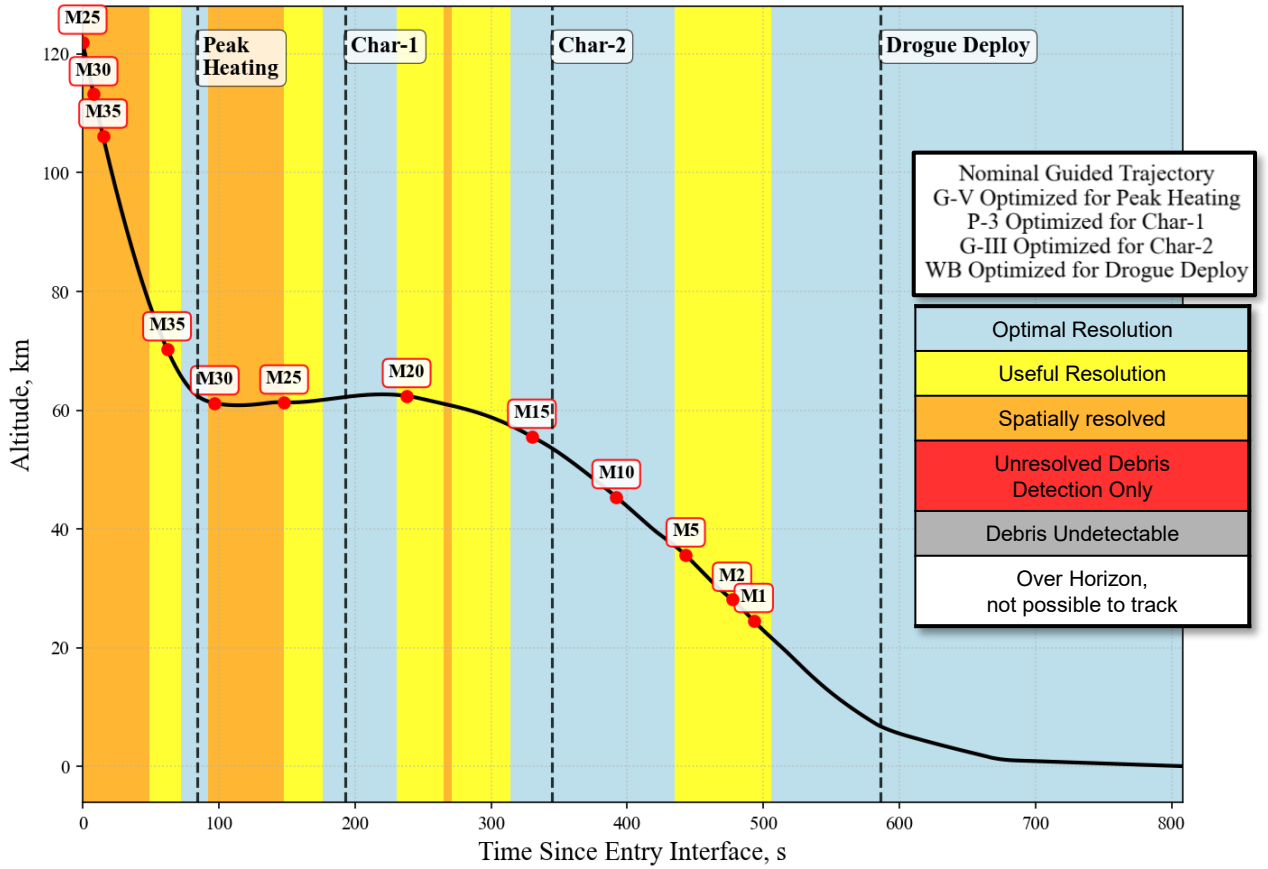
Total LP-19 Reentry Aircraft Selection

	Asset	Purpose	Altitude	Number of Sensors	Primary Payloads
	**NASA 95** Gulfstream V **N95NA**	**Orion TPS** ▪ Peak Heating Temperature Distribution ▪ Calibrated thermal imagery & spectroscopy ▪ Live Streaming	**FL405** FL400B410	**6 Total** VIS / NIR / SWIR / MWIR **HD + 4K**	**MIDAS:** ✓ SAMI ✓ UHD-1 ✓ CALSPEC
	**USN Bloodhound 300** P-3 Orion **BH300**	**Orion TPS** ▪ Char loss (shoulder) ▪ Debris detection ▪ Calibrated thermal imagery	**FL250** FL250B300	**12 Total** VIS / NIR / SWIR / MWIR / LWIR **SD + HD**	**Cast Glance:** ✓ NIR Track 1
	**NASA 808** Gulfstream III **N808NA**	**Orion TPS** ▪ Char loss (dish) ▪ Debris detection ▪ Calibrated thermal imagery	**FL400** FL400B420	**5 Total** VIS / NIR / SWIR **HD + 4K**	**MIDAS:** ✓ TRISPEC ✓ UHD-2 ✓ DVSMDA
	**MDA HALO-II** Gulfstream 550 **N552HA**	**Orion TPS** ▪ Char loss (dish) ▪ Debris detection ▪ Calibrated thermal imagery	**FL430** FL430B470	**17 Total** VIS / NIR / SWIR / MWIR / LWIR **SD + HD**	**HALO** ✓ VIS ✓ MWIR ✓ LWIR
	**USAF RTB** NT-43A **AF1155**	**Orion LRS + Launch Imagery** ▪ Launch Photodocumentation ▪ Reentry Photodocumentation ▪ Asset technical Assessment	**FL300** FL300B350	**4 Total** VIS / MWIR / LWIR **SD**	**ACP** ✓ VIS ✓ IR
	**NASA 926** WB-57 **N926NA**	**Orion LRS + Launch Imagery** ▪ FBCP & Drogue chute deploy ▪ Calibrated thermal imagery ▪ Live Streaming	**FL200** FL190B280	**2 Total** VIS / MWIR **HD**	**DyNAMITE** ✓ VIS ✓ MWIR
	**WESCAM Wildcard01** Cessna 208 **N97826**	**Orion LRS + Launch Imagery** ▪ Launch Photodocumentation ▪ Drogue & Main chute deploy ▪ Live Streaming	**FL120** FL120B150	**6 Total** VIS / SWIR / MWIR **HD + 4K**	**MX-20** ✓ VIS ✓ SWIR ✓ MWIR

Aircraft Placement

- Aircraft placement was determined using the following inputs:
  - Aircraft performance (service ceiling, airspeed, bank angle)
  - Sensor specifications and gimbal limits (azimuth/elevation limits, sensor wavebands, integration time)
  - Orion trajectory geometry (view angle to heatshield)
  - Imaging requirements provided by Orion (spatial resolution, key mission events)
- Spatial resolution coverage graphs were generated placing various aircraft at different key mission events along the trajectory
- Using the inputs above, various mission configurations were developed and presented to the Orion program.
- After iterating with stakeholders, the agreed upon mission solution was to have four aircraft covering the main key mission events, and additional aircraft placed at the highest priority events for redundancy.





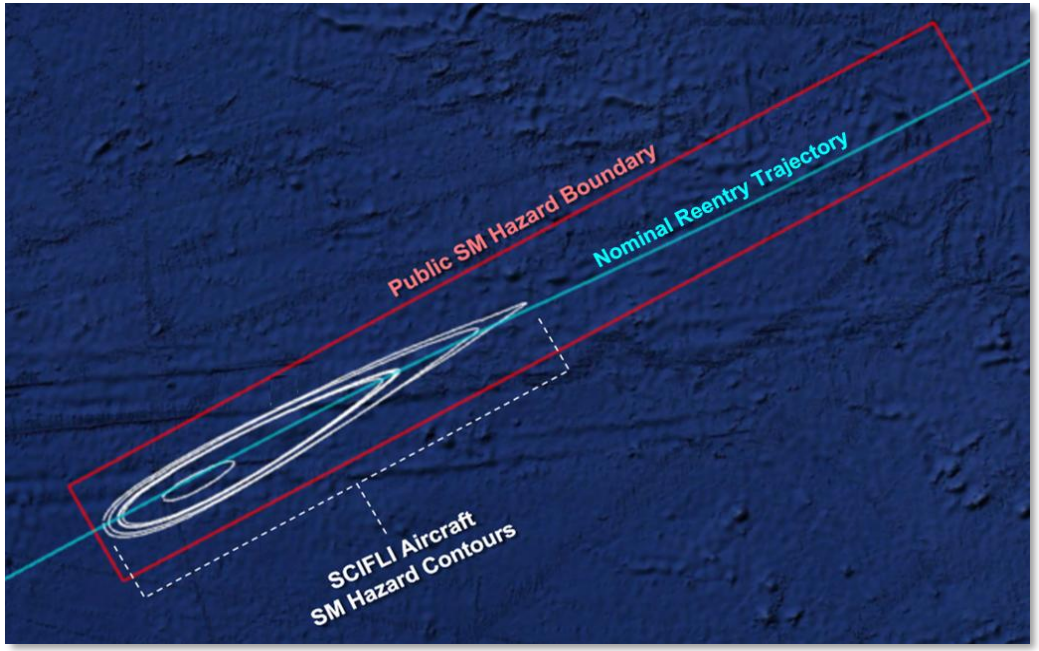
Spatial Resolution Coverage Graph with G-V, P-3, G-III, and WB-57 flying against a Nominal Guided Trajectory (above) and Associated Aircraft Placement Along Trajectory (left)

External Constraints

After determining ideal aircraft location along the trajectory, one must consider real world constraints that may affect aircraft placement.

Spacecraft Hazard Boundaries

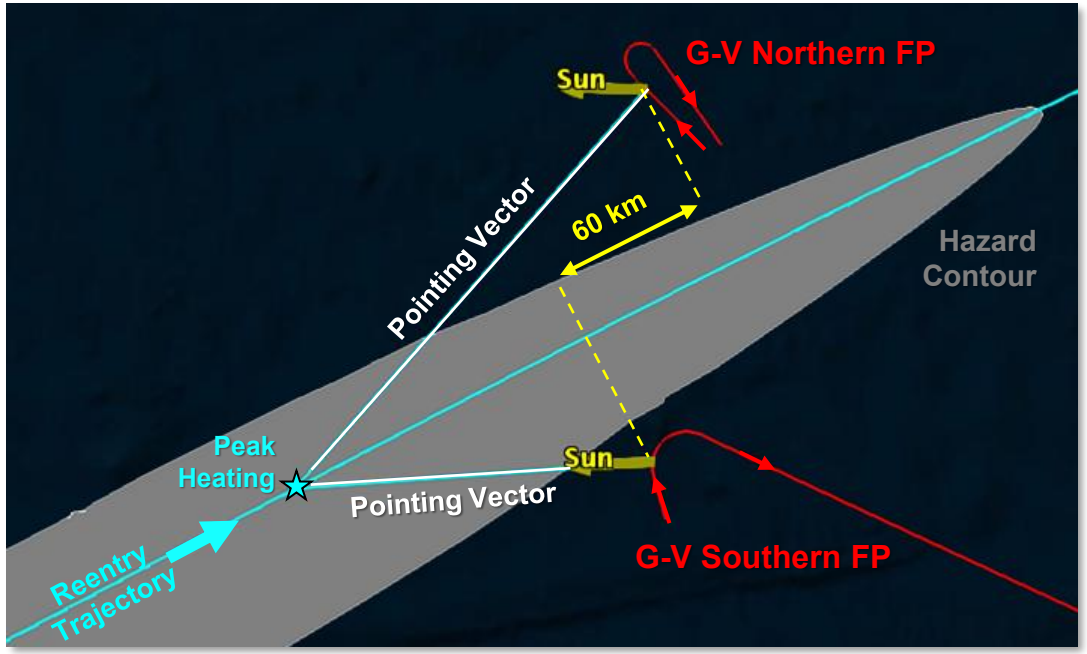
- Public hazard boundaries prevent public vehicles from entering an area with over 1E-6 Probability of Casualty (Pc) due to spacecraft debris.
- Aircraft deemed Mission Essential/Critical Ops can accept a higher risk, up to 1E-15 Pc and fly closer to the spacecraft trajectory.
- Specific hazard contours were generated for each SCIFLI participating aircraft based upon aircraft size, speed, and altitude.



Public Hazard Boundary for Orion Service Module (SM) compared to SCIFLI Participating Aircraft Hazard Contours for SM

Sun Angles

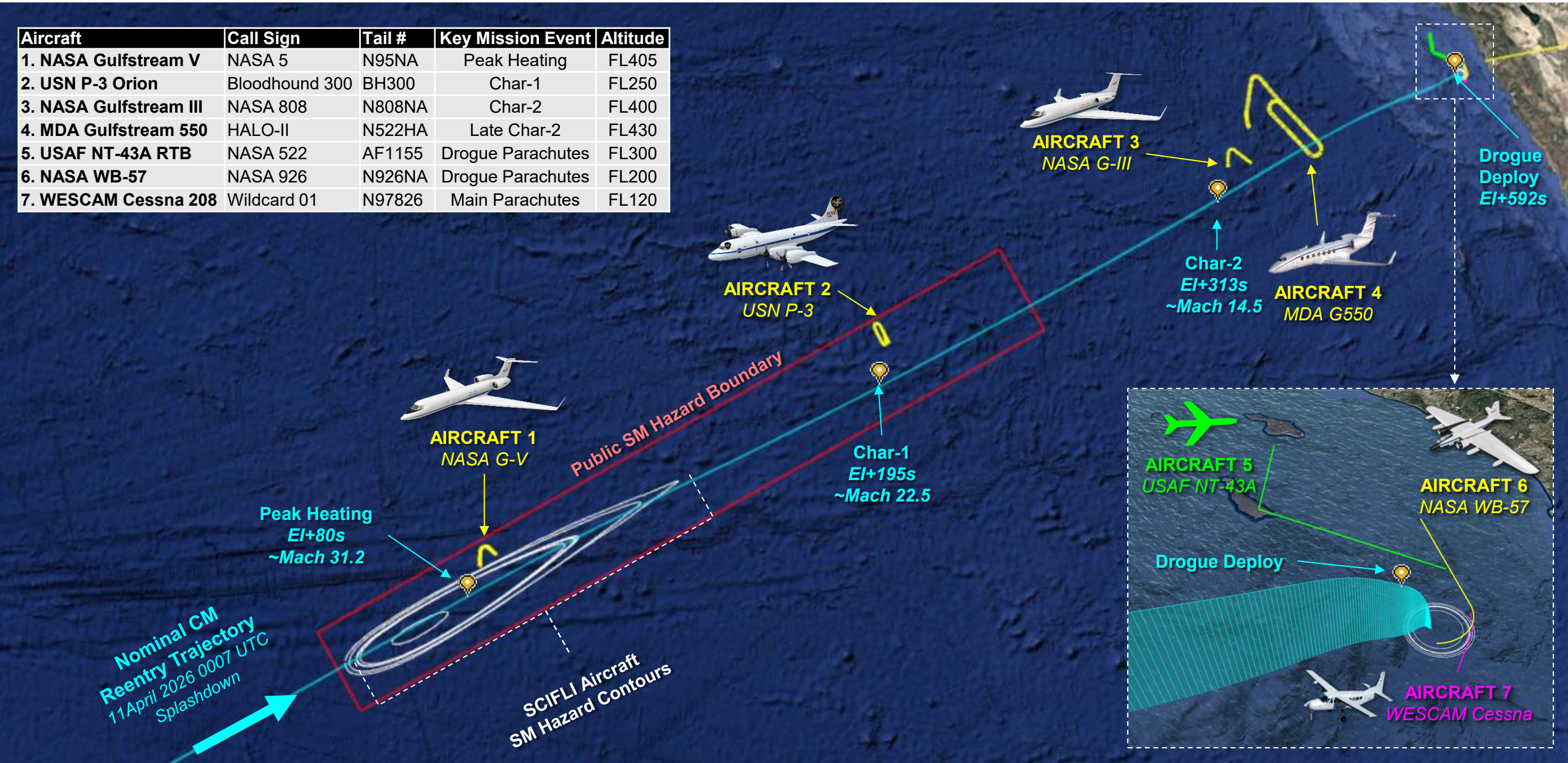
- Flight paths for many of the aircraft were planned to be on the south side of the trajectory because of sensor location.
- When the reentry slipped into LP-19, the sun angles introduced additional constraints to the flight path placement, necessitating a shift in flight path from south to north of the trajectory.
- This resulted in degraded spatial resolution due to larger slant range.



North vs South Gulfstream V Flight Path Configurations
Note how the pointing vector coincides with the sun vector on the southern path

LP-19 Reentry Theater of Operations

Aircraft	Call Sign	Tail #	Key Mission Event	Altitude
1. NASA Gulfstream V	NASA 5	N95NA	Peak Heating	FL405
2. USN P-3 Orion	Bloodhound 300	BH300	Char-1	FL250
3. NASA Gulfstream III	NASA 808	N808NA	Char-2	FL400
4. MDA Gulfstream 550	HALO-II	N522HA	Late Char-2	FL430
5. USAF NT-43A RTB	NASA 522	AF1155	Drogue Parachutes	FL300
6. NASA WB-57	NASA 926	N926NA	Drogue Parachutes	FL200
7. WESCAM Cessna 208	Wildcard 01	N97826	Main Parachutes	FL120



Aircraft Basing Locations

Aircraft	Basing Location
1. NASA Gulfstream V	NAS Pt. Mugu (KNTD)
2. USN P-3 Orion	NAS Pt. Mugu (KNTD)
3. NASA Gulfstream III	NAS Pt. Mugu (KNTD)
4. MDA Gulfstream 550	Phoenix Goodyear (KGYR)
5. NASA WB-57	March AFB (KRIV)
6. WESCAM Cessna 208	Carlsbad (KCRQ)
7. USAF NT-43A RTB	Edwards AFB (KEDW)

Reentry Dress Rehearsal Flights

Two simulated trajectories were flown against by a portion of the mission aircraft to practice multi-aircraft imaging ops (comms tests, airspace coordination, mission coordination at MCC, sensor operations, etc.) contributing to overall mission assurance.

Test Event	Reentry Dress Rehearsal 1	Reentry Dress Rehearsal 2	Mission Flight
Location	Pacific Ocean	Pacific Ocean	Pacific Ocean
Participating Aircraft	**1. NASA Gulfstream V** **2. USN P-3 Orion** **3. NASA Gulfstream III** **4. MDA Gulfstream 550**	**1. NASA Gulfstream V** **2. USN P-3 Orion** **3. NASA Gulfstream III** **4. MDA Gulfstream 550** **5. NASA WB-57** **6. USAF 737-200 RTB**	**1. NASA Gulfstream V** **2. USN P-3 Orion** **3. NASA Gulfstream III** **4. MDA Gulfstream 550** **5. NASA WB-57** **6. USAF 737-200 RTB** **7. WESCAM Cessna 208**
Date (PDT)	31 MAR 2026 (L+1d)	8 APRIL 2026 (R-2d)	10 APRIL 2026
Details	• Early return primary assets in reentry mission airspace with full complement of research personnel. • Verification of airborne system performance **prior to SLS Launch to be prepared for any early return scenarios**. • Testing SCIFLI Mission Control communications paths. • Flight crew engagement with civilian and military ATC controllers, as necessary. • Mission timing simulations.	• All aircraft in real reentry mission airspace with full complement of research personnel. • Testing SCIFLI Mission Control communications paths. • Reviewing safety procedures. • Flight crew engagement with civilian and military ATC controllers, as necessary. • **Targeting real mission timing and nominal reentry path to test mission cadence and sun angles**	• Fly all research aircraft against real imaging target. • Collect data.

Contingency Coverage Plan

- Created a detailed contingency plan for utilization of assets in the event a primary coverage aircraft is unavailable for its assignment.
- The plan informed weather-based contingency decisions.
- HALO-II would be utilized to backfill up-range TPS assets, where appropriate.

Scenarios Considered:

- Contingency A: WB-57 is unavailable for launch but can recover for reentry support.
- Contingency B: G-V is unavailable for reentry support.
- Contingency C: P-3 is unavailable for reentry support.
- Contingency D: G-III is unavailable for reentry support.
- Contingency E: WB-57 is unavailable for reentry support.

Assumptions:

- G-V should be utilized for launch coverage if WB-57 becomes unavailable prior to L-24hrs.
- If WB-57 becomes unavailable after L-24hrs, G-V will stay on the west coast to support early returns.

Abort Mode	Timeline	Observation Goal	Nominal WB-57 @ Launch	Contingency A G-V @ Launch	Contingency B No G-V	Contingency C No P-3	Contingency D No G-III	Contingency E No WB-57
LAS	Launch	High Altitude Engineering Imagery	WB-57	G-V	WB-57	WB-57	WB-57	WB-57
		Low Altitude Photo-documentation	Cessna USAF	Cessna USAF	Cessna USAF	Cessna USAF	Cessna USAF	Cessna USAF
AOA / LEO	LEO Aborts *Splash ~L+1h → 27h*	No High-Altitude Imagery Coverage						
HEO	Post-ARB Abort Coverage *Splash ~L+27h*	Peak Heating	G-V	P-3	P-3	G-V	G-V	G-V
		Char1	P-3	G-III	HALO	HALO	P-3	P-3
		Char2	G-III	HALO	G-III	G-III	HALO	HALO
		FBC/Drogue/Main	HALO					
	Post-PRB Abort Coverage *Splash ~L+49h → 52h*	Peak Heating	G-V	G-V	P-3	G-V	G-V	G-V
		Char1	P-3	P-3	HALO	HALO	P-3	P-3
		Char2	G-III HALO	G-III HALO	G-III	G-III	HALO	G-III HALO
		FBC/Drogue/Main	WB-57 Cessna	WB-57 Cessna	WB-57 Cessna	WB-57 Cessna	WB-57 Cessna	Cessna
Early Return	Post-TLI Abort Coverage *Splash ~L+79h → 5d*	Peak Heating	G-V	G-V	P-3	G-V	G-V	G-V
		Char1	P-3	P-3	HALO	HALO	P-3	P-3
		Char2	G-III HALO	G-III HALO	G-III	G-III	HALO	G-III HALO
		FBC/Drogue/Main	WB-57 USAF Cessna	WB-57 USAF Cessna	WB-57 USAF Cessna	WB-57 USAF Cessna	WB-57 USAF Cessna	USAF Cessna
Nominal	Nominal Reentry Coverage *Splash ~9d*	Peak Heating	G-V	G-V	P-3	G-V	G-V	G-V
		Char1	P-3	P-3	HALO	HALO	P-3	P-3
		Char2	G-III HALO	G-III HALO	G-III	G-III	HALO	G-III HALO
		FBC/Drogue/Main	WB-57 USAF Cessna	WB-57 USAF Cessna	WB-57 USAF Cessna	WB-57 USAF Cessna	WB-57 USAF Cessna	USAF Cessna

Partially Meets Imagery Objectives

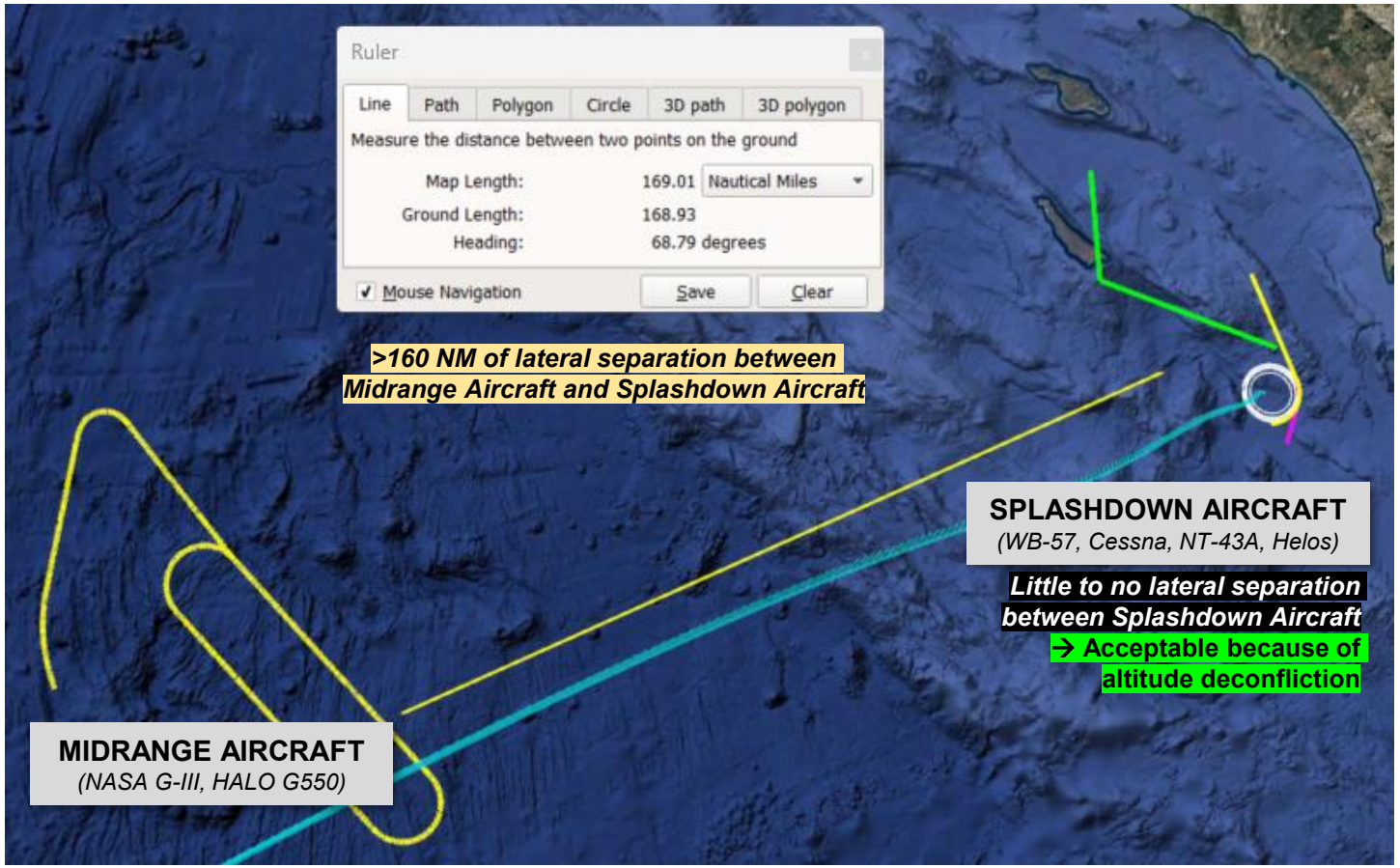
No High-Altitude Coverage

Airspace Coordination

- Airspace reservations and routing through Military Test Ranges
  - Naval Air Warfare Center (NAWC) / Point Mugu Sea Range (PMSR)
  - Fleet Area Control and Surveillance Facility (FACSFAC) San Diego
- Positional reports and Airspace Reservations (ALTRVs) through FAA ATC
  - LA Center (controls airspace up to about 20 NM off the coast of CA)
  - Oakland Oceanic (controls airspace over the Pacific beyond the test ranges)
  - Central altitude Reservation Function (CARF) built and filed ALTRVs for aircraft outside of the test ranges
- Off-nominal support coordination with Search and Rescue (SAR) forces
  - Pacific SAR support forces based at Joint Base Pearl Harbor Hickam would deploy to provide medical support while awaiting a recovery ship if the Crew Capsule lands at an off-nominal location/time and requires emergency support.
  - For some splashdown locations, a SCIFLI asset may have been first overhead at the capsule landing location and may have been asked to provide imagery, monitoring, and/or communications relay while SAR forces are in transit

Altitude Deconfliction

- For any aircraft flying at similar altitudes, sufficient lateral separation was ensured.
- For any aircraft flying in similar areas and not able to separate laterally (e.g., WB-57, NT-43A, and Cessna all at splashdown), flight plans were developed to ensure altitude separation using altitude blocks.



NASA 522 – FL300B350

2,000 ft of altitude separation

NASA 926 – FL190B280

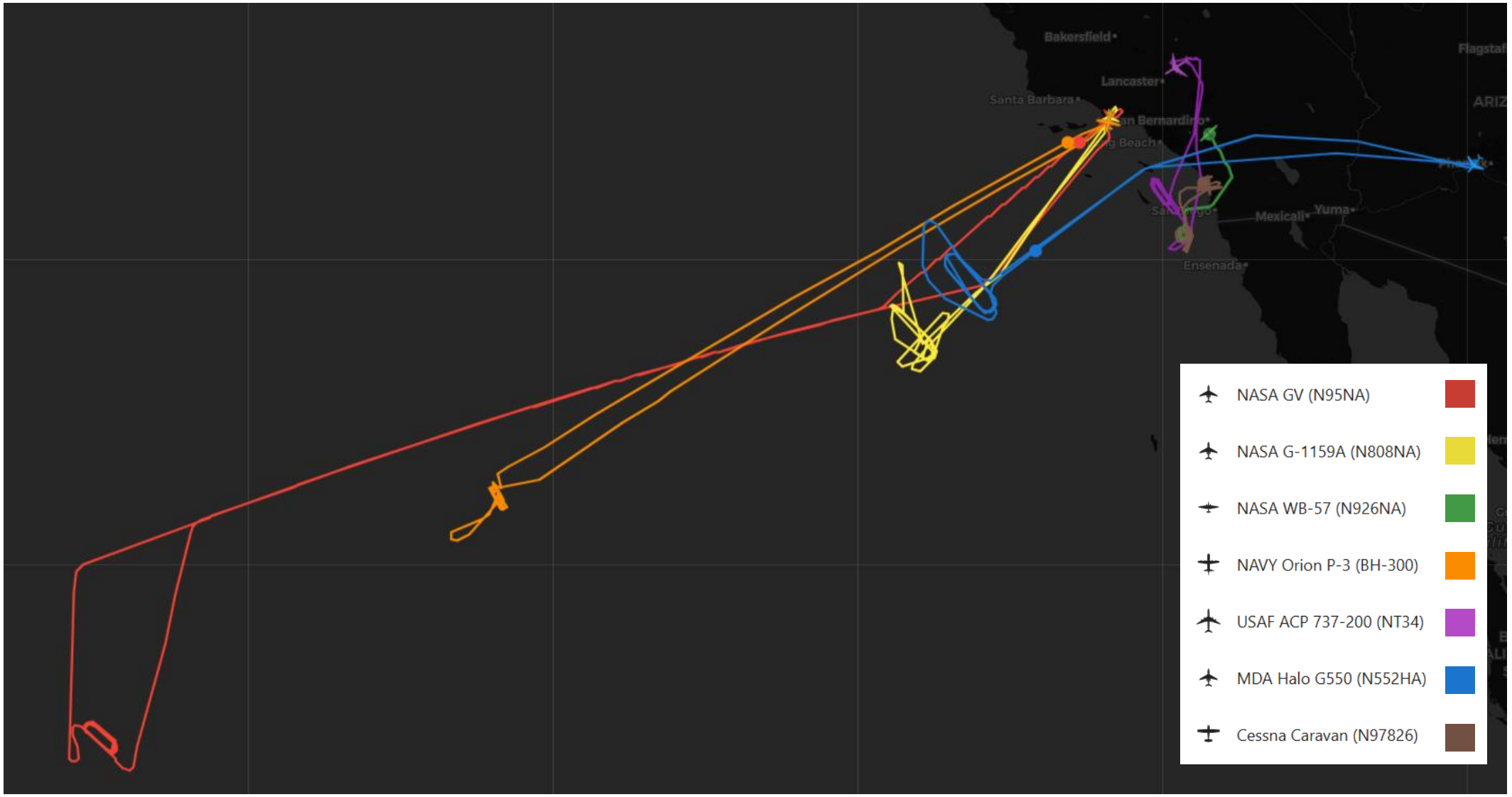
4,000 ft of altitude separation

Wildcard01 – FL120B150

2,000 ft of altitude separation

USN Helos – FL060B100

As-flown Mission Day Flight Paths



Mission Success!

Peak Heating captured by G-V
UHD Payload, NIR

Splashdown captured by WB-57
DyNAMITE Payload, Visible

All airborne imagery assets collected multispectral imagery of the Orion reentry.
Creating comprehensive coverage of Artemis II Orion reentry from Entry Interface through Splashdown.

Questions?

Aircraft Based at NAS Pt. Mugu (G-V, P-3, G-III)

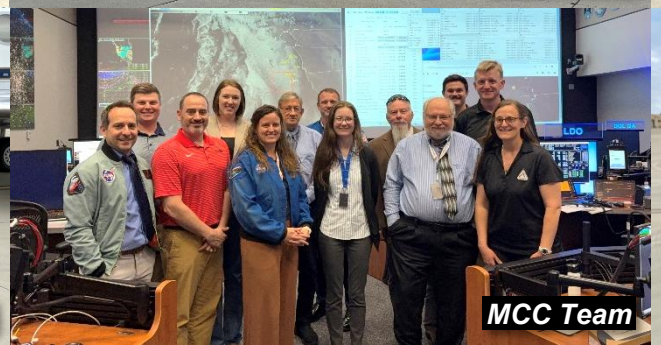

G-V Team

P-3 Team

G-III Team


WB-57 Team


SCIFLI PM Team


MCC Team


AFRC Team


Artemis II Crew on G-V