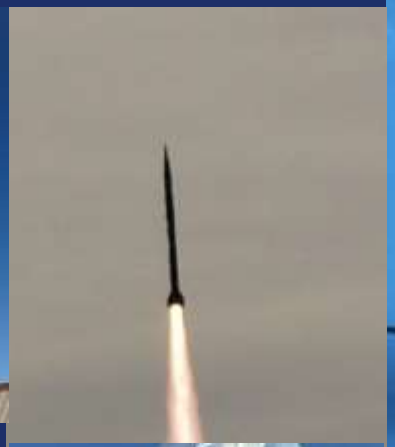
Incremental Flight Testing of Automatic Dependent Surveillance – Broadcast (ADS-B) Prototype for Commercial Space Transportation Applications

Federal Aviation Administration



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To: ITEA 32nd Annual International Test and Evaluation Symposium

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Overview

- Acknowlegements
- Background
- Early Testing
- Upgrades as a result of Testing and Analysis
- ADS-B Integration on Spaceloft (SL) Vehicles
- SL-8 Flight Data and Analysis
- Lessons Learned
- Terminal Velocity Aerospace Drop Test
- Technical Maturation Plan

Acknowledgements

Experiments were conducted with cooperation and resources from:

- NASA Wallops Flight Facility
- NASA Flight Opportunities Program (FOP)
- MITRE Corporation
- FAA Technical Center (Atlantic City, NJ)
- New Mexico State University (NMSU)
- Operationally Responsive Space (ORS) Office
- UpAerospace Inc.
- Masten Space Systems
- Near Space Corporation
- Terminal Velocity Aerospace

Resources, support and cooperation from all were vital for the opportunities to incrementally flight test the payload!

BACKGROUND

US Commercial Space Transportation

Diversity of Vehicles and Operations

Air Launch

Stratospheric Manned Balloons*

Sea Launch

Ground Launch

Reusable Launch Vehicles

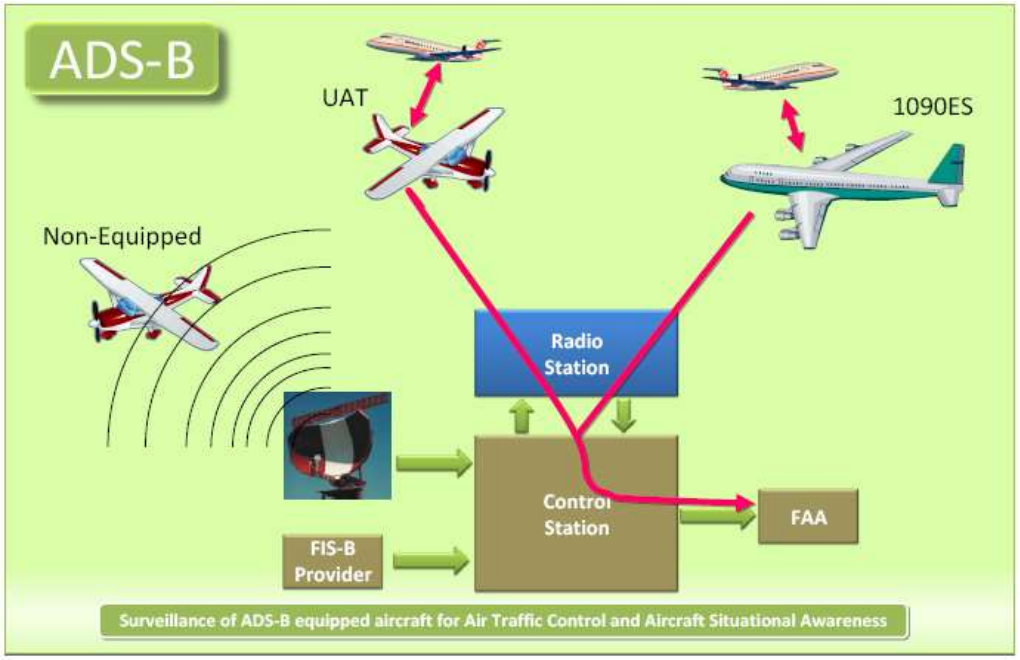
Suborbital Rockets

Over 200 licensed commercial launches safely conducted since 1987

*** With Environmental Control and Life Support System (ECLSS)**

What is ADS-B?

- **Automatic**
  - Messages are sent out periodically without interrogation (unlike transponder)
- **Dependent**
  - Dependent on a position source onboard the aircraft
- **Surveillance**
  - Primary purpose is for ATC to know where aircraft are
- **Broadcast**
  - Messages are broadcast



•*Source: FAA SBS ICD Draft 0.64*

ADS-B Out: Transmitting from aircraft
ADS-B In: Receiving by aircraft

UAT: Universal Access Transceiver – 978 MHz
1090 ES: Extended Squitter – 1090 MHz

FAA ADS-B Deployment

- **Baseline deployment of 634 radio stations is complete**
- **Each radio station has a minimum line-of-sight range requirement (i.e., radius) of 250 nautical miles based on latitude/ longitude distance (altitude is not limiting factor)**
  - Actual coverage may be up to 300 nmi radius (currently limited by radio station software configuration)

•Source: MITRE

Purpose of Task

- **Support of suborbital reusable launch vehicles (sRLVs) and other commercial space vehicles requires considerations for safe integration into the national airspace system (NAS)**

- **ADS-B technology is used for surveillance by air traffic control and situational awareness for pilots**

- **This research presents the potential for adaptation of existing ADS-B technology to support operations for sRLVs operations exceeding current technology limits (primarily altitude, velocity and acceleration)**

MITRE UBR-TX

- **UAT Beacon Radio – Transmit Only (UBR-TX)**
  - Broadcasts state vector once per second
  - Supports both barometric and GPS-based altitudes
  - 4G acceleration /1000Kts velocity limits
  - Altitude limit spec 60Kft (actually 76Kft)
- **Balloon / Rocket Flight Tests**
  - 2008 Red Glare V (amateur rocket)
  - 2009 Red Glare VII (amateur rocket)
  - 2010 AFRL research balloon
  - 2010 NASA Wallops sounding rocket
  - 2012 Up Aerospace Spaceloft 6
  - 2012 Team America Rocket Challenge
  - 2013 Up Aerospace Spaceloft 7
  - 2013 Masten Xombie

MITRE®
TECHNOLOGY APPLIED

Upgrades by ERAU

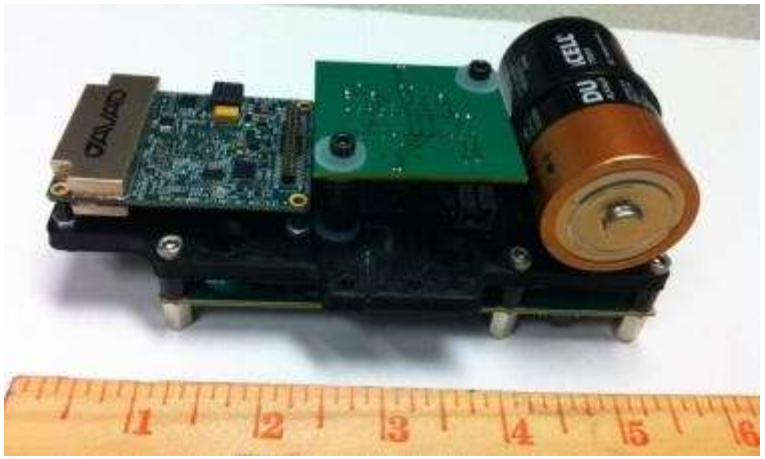
Based largely on lessons learned from testing

Hardware

- **GPS: Javad TR-G2**
- **Daughterboard**
  - Power regulation
  - Logic conversion
- **UBR Board**
  - Replaced components with milspec equivalents (when possible)
- **Ruggedization**
  - New enclosure
  - Epoxy
  - Neoprene
  - Ecosorb EMI/RFI

Software

- **Reuse/adapt MITRE software**
- **GPS software parser**
  - From SiRF binary protocol to Javad GREIS binary protocol
- **Maximum message altitude accomodated**
  - Does not “cut off” at >60,000 feet



Parameter	Specification
Length	5.75” (14.6 cm)
Width	2.5” (6.35 cm)
Height	2.5” (6.35 cm)
Weight (UBR board, daughter board, GPS, battery, and enclosure)	790 g (27.9 oz)
Weight (cables, antennas, etc.)	85-300g est.
Nominal power Consumption	840mA @ 3VDC
Nominal battery capacity	7.75 Ah

UBR-ERAU Advanced ADS-B Transmitter for sRLVs

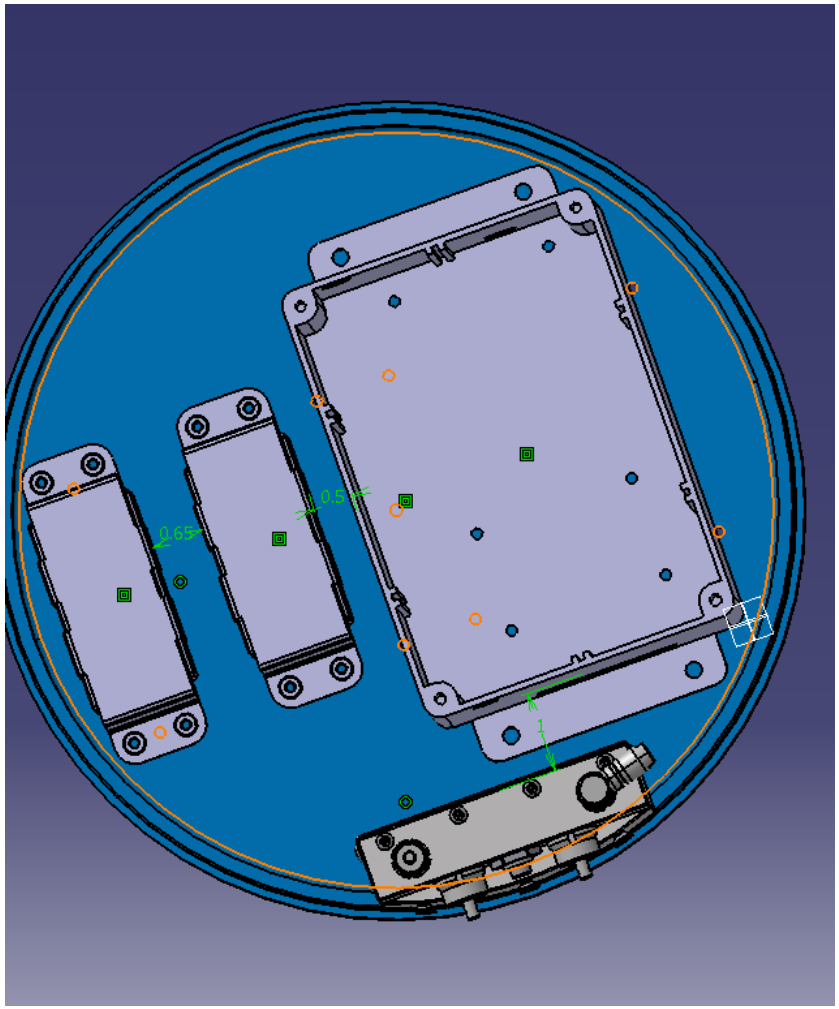
Maximum Altitude (geometric), MSL	94,025 ft.
Maximum Altitude (pressure), MSL	94,200 ft.
Flight Time – Ascent	116 minutes
Flight Time – Float	58 minutes
Flight Time – Descent	38 minutes
Flight Time – Total	212 minutes
Total Number of Unique GBTs Receiving Data	31 (available in post-process)
Number of GBTs Tracking at Apogee	11 (available in post-process)

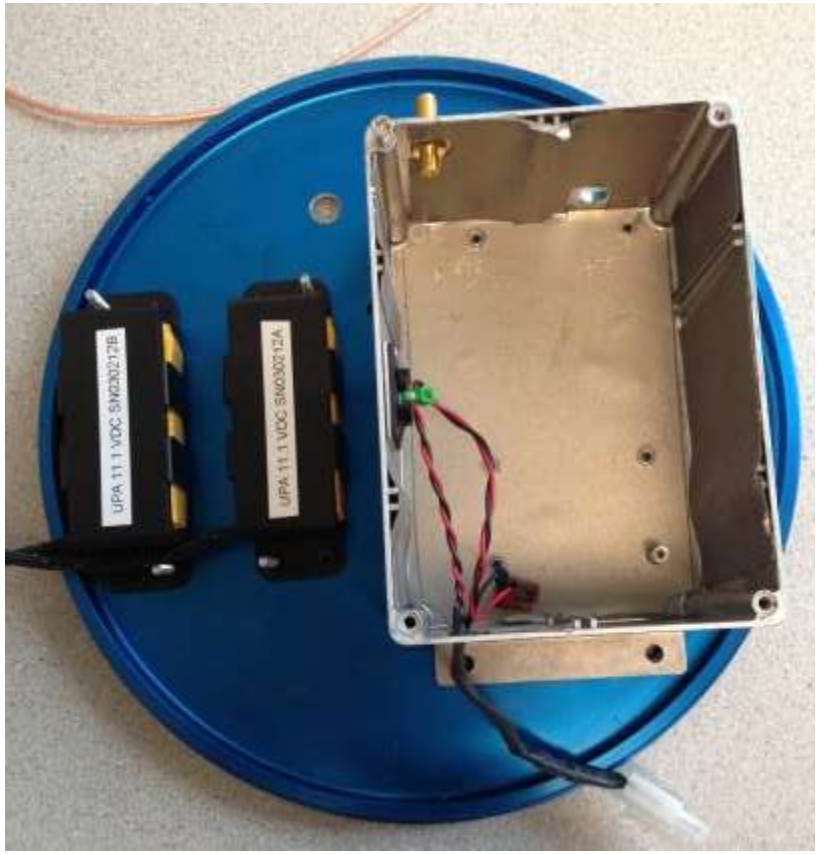
Near Space Corporation NBS
January 22, 2013 and
February 15, 2014 (data shown, left)

Images courtesy of UpAerospace Inc.

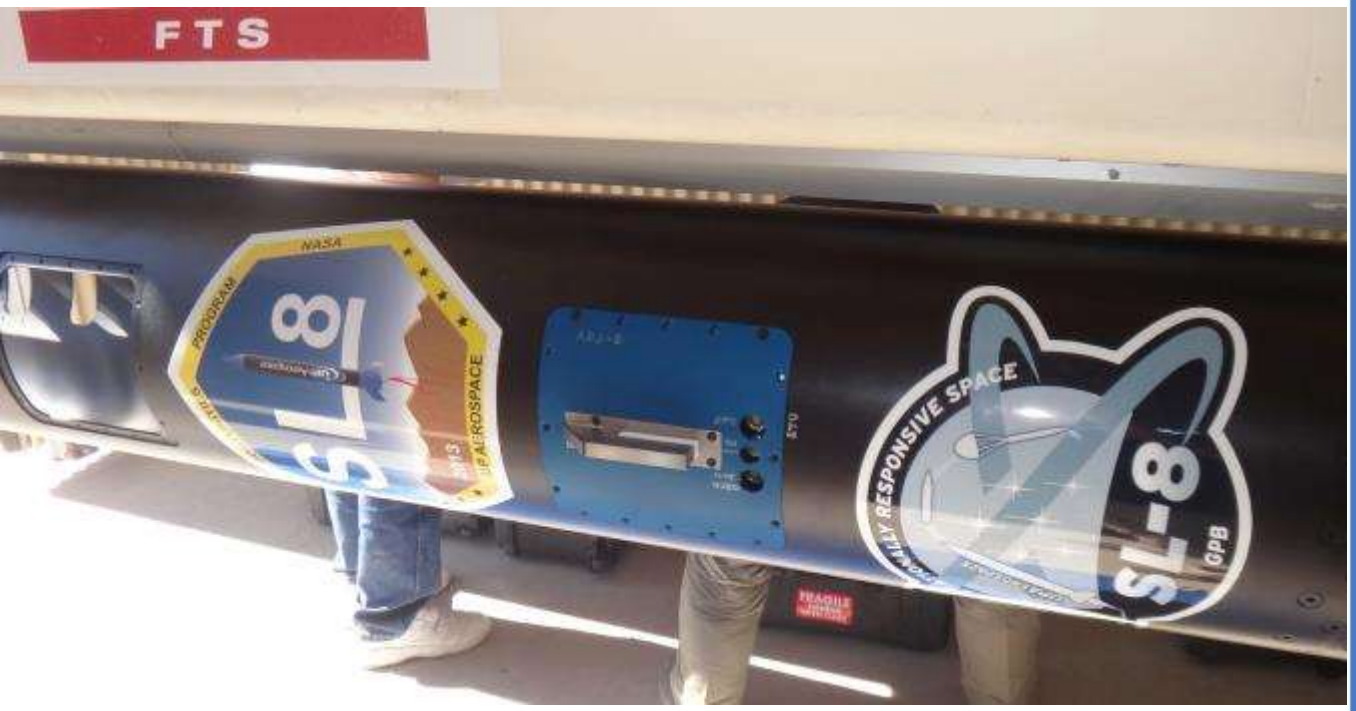
INTEGRATION FOR SPACELOFT XL

PTS-10 Rocket Segment





Vehicle Integration



Images courtesy of UpAerospace Inc.

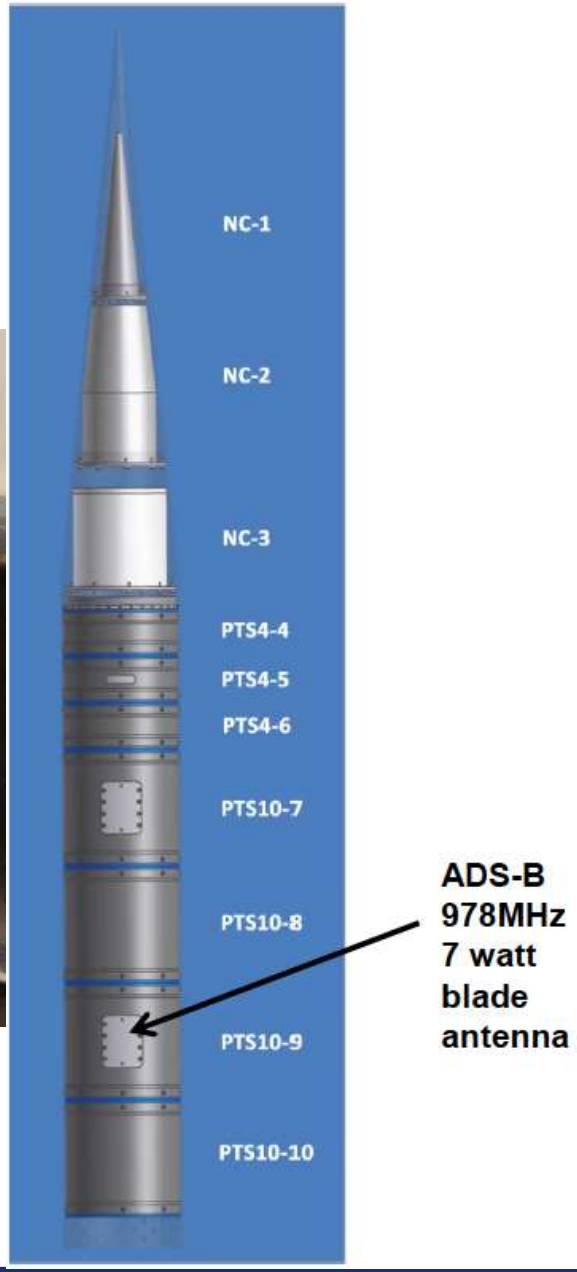
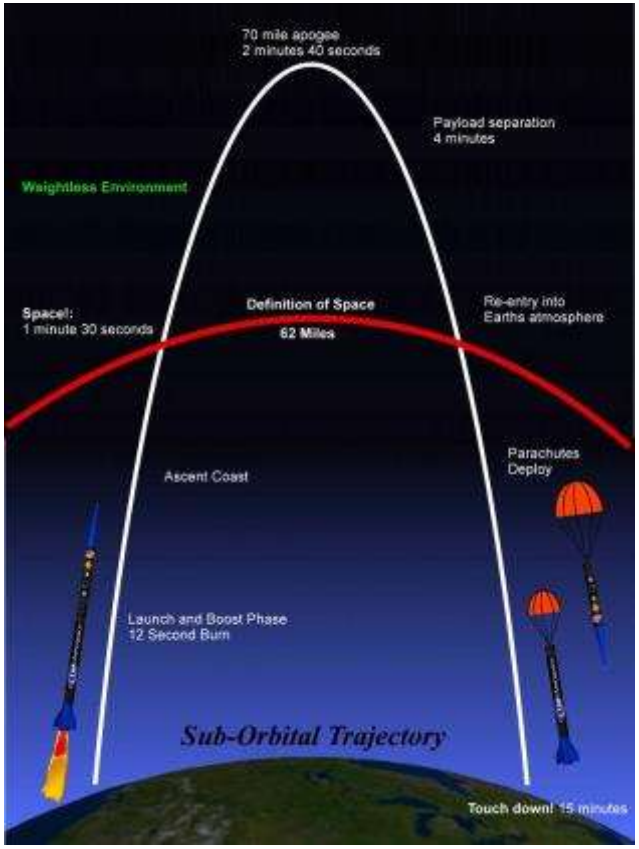


Image courtesy of UpAerospace Inc.

SL-8 FLIGHT DATA AND ANALYSIS

SL-8 Flight Profile

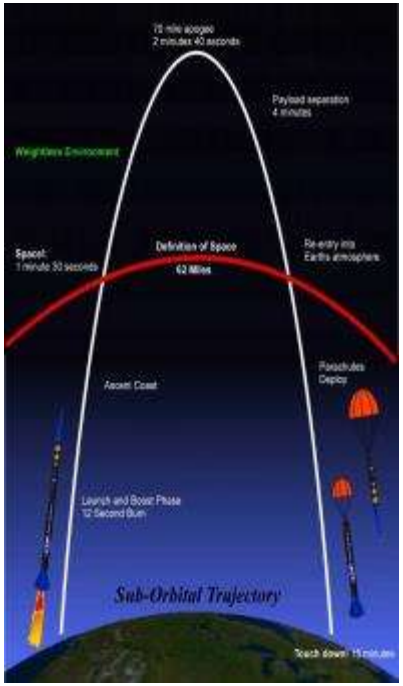
Event	Time (seconds)
Launch	T + 0
Despin initiated	T + 55
Apogee (384,100 ft.)	T + 162
Payload separation	T + 240
Drogue deployment	T + 442
Chute Deployment	T + 452
Touchdown	T + 751



Typical Spaceloft Flight Profile

Flight Analysis

Phase of flight	Metric	Result
Full flight	% tracked by ADSB	73.8%
T + 62 (7 seconds post-despin initiation)	% of flight tracked by ADS-B	80.5
	Avg. time between message	1.27 s
	Max. time between message	8.00 s
	Max receivers tracking (FAA/Excelis Ground Based Transceivers [GBTs] only)	8
	Max receivers tracking (FAA GBTs and portable)	10
	Avg. latitude error	16.145E-05 deg.
	Avg. longitude error	9.170E-05 deg.
	Avg. altitude error (below 101,350 ft.)	54.31 ft.
After T+315 (descent and deceleration to less than 1000 ft./sec)	% of flight tracked by ADS-B	95.9%
	Avg. time between message	1.04 s
	Max. time between message	3.00 s



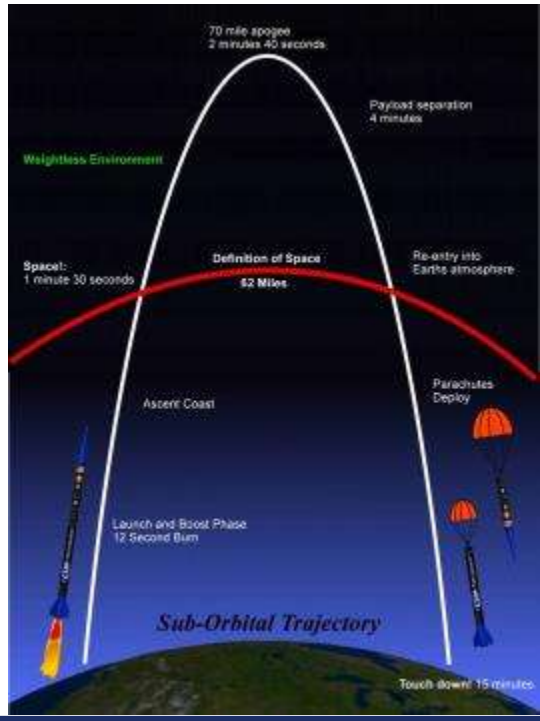
Typical Flight Profile

Performance vs. Success Criteria

Criteria	Pass / Fail	Comments
Broadcasts well-formed messages	Pass	FAA GBTs and two portable Garmin GDL 90 successfully parsed data
Vehicle tracking for 90% of flight	Fail	73.8% of full flight, 80.5% post-despin, and 95.9% on descent.
Characterization of data loss	Pass	Primary characterization of data loss was configuration onboard spacecraft and NOT ADS-B unit itself.
Correlated with other data sources	Pass	Utilized truth data from WSMR primary radar. Position/altitude accuracy measured.

Summary of SL-8 Results

- **Advanced ADS-B Payload (with unrestricted GPS processor) flew on Spaceloft-8 (SL-8) mission from Spaceport America into WSMR in Nov 2013**
- **Successfully transmitted messages entire flight (first flight of this payload on a rocket!)**
- **Successfully transmitted GPS filled messages for all but first 63 sec of flight (design of experiment limitation)**
- **Got GPS "lock" after de-spin from 7Hz rotation**
- **Valid lat /long from T+63 sec**
- **Valid alt when below ADS-B 978MHz message limit of 101,350 feet**



LESSONS LEARNED

Lessons learned

- **Two prior flights with "basic" MITRE ADS-B payload w/NMSU minimized risk of vehicle integration and site support**
- **Payload demonstrated to be viable for tracking sub-orbital RLV or sounding rocket of this velocity, altitude and range**
  - Additional transmit antennas and transmission power desirable for longer range, higher altitude flights
  - Single transmit antenna briefly blocked by rocket body at apogee
- **Current GPS antennas and amplifier may not be sufficient to maintain lock through all phases of flight**
  - Until vehicle de-spin, payload receives intermittent stream of GPS
- **Desirable for future missions to have onboard inertial measurement unit with payload and/or telemetry to correlate with data received (future SL missions will have telemetry)**
- **Desirable to equip future vehicles that host payload with GPS translator (s)**
  - Record raw GPS data for post-flight analysis / truth data

PAYLOAD MATURATION

Technology maturation plan

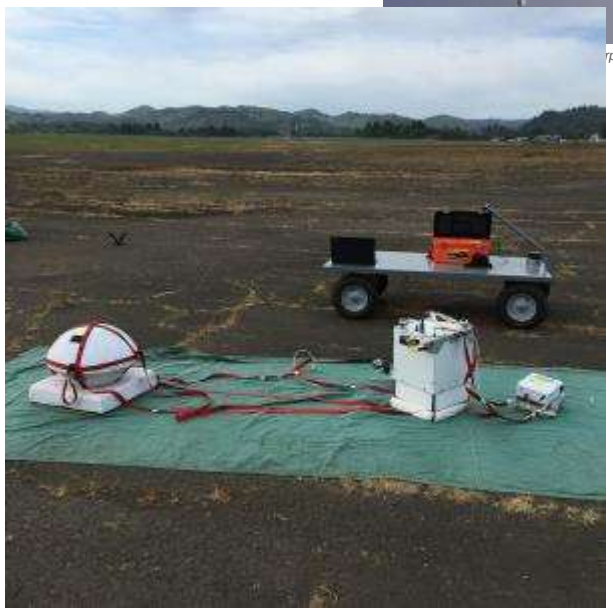
- **Project goal to demonstrate viability and test functional envelope of experimental ADS-B payload for sub-orbital commercial space operations**
  - TRL-7, proven within its operational environment
- **Additional flights needed before transition to TRL-8 (i.e. move out of prototype phase)**
- **Diversity of new vehicles is desirable to get operator feedback**

Terminal Velocity Aerospace Reentry Vehicle

Drop from stratospheric balloon

- **NASA funded**
- **Initial phase of plans to integrate payload into a reentry vehicle**
- **Dropped from 100Kft - ADS-B payload reported all times in flight**
- **Was useful in finding vehicle in landing location in forest!**
- **Balloon gondola also had ERAU ADS-B out payload**

- first known with flight with ADS-B on both balloon and payload



Terminal Velocity Aerospace Reentry Vehicle
Drop from stratospheric balloon

Planned Future Commercial Space Flights with Experimental ADS-B Payloads

•Source: Near Space Corporation

- **Near Space Corporation's High Altitude Shuttle System**
  - Surrogate winged suborbital vehicle performing a descent into NAS (from above 60, 000 feet)
- **Virgin Galactic SpaceShipTwo**
  - Demonstrate on a commercial spacecraft for human occupancy
  - Currently in planning stages for integration under NASA FOP
- **Expendable Launch Vehicle**
  - Currently in planning stages
- **Cubesat or International Space Station**
  - Investigating opportunities for cubesat integration or a ISS flight
  - Proof of concept for on-orbit application

Questions?

Image courtesy of UpAerospace Inc.