COE CST Fifth Annual Technical Meeting

Task 306 UAT ADS-B Research and Demonstration for Commercial Space Applications: Progress Report

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Student:

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October 27-28, 2015
Arlington, VA

Agenda

- Team Members
- Project Overview
- Collaboration with Terminal Velocity Aerospace
- Maturation plan and follow-on research plans

Team Members

- **People**
  - Principal Investigators: Richard S. Stansbury
  - Students: Brandon Neugebauer, Richard P. Day, Yosvany Alonso, Dyland Rudolph, and Dominic Tournour
  - Other faculty: William C. Barott, Massood Towhidnejad
  - FAA: Nick Demidovich, Chuck Greenlow, John Dinofrio, and others.
  - MITRE: Dave Edwards

- **Organizations**
  - Terminal Velocity Aerospace, LLC.
    - Dominic Depasquale
  - NASA Flight Opportunities Program
    - Up Aerospace
    - Near Space Corporation

Goals

- Enhance tracking of vehicles as they traverse through the national airspace system to mitigate the impact of commercial space operations on routine aviation operations

- Sub-goals goals:
  - Determine suitability for ADS-B for commercial space
  - Determine boundary conditions of system performance
  - Assess performance of prototypes on space vehicles and suitable analogues
  - Identify areas of improvement in ADS-B standard to accommodate ADS-B operation
  - Provide stakeholders with information regarding suitability of ADS-B as a primary or secondary tracking source

MITRE UBR-TX

- UAT Beacon Radio – Transmit Only (UBR-TX)
  - Broadcasts state vector once per second
  - Supports both barometric and GPS-based altitudes
- 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

Past Flights:

- **NSC Nano Balloon System**
- **NSC High Altitude Shuttle System**
- **Up Aerospace SpaceLoft-8**
- **NSC Small Balloon System w/ TVA Spacecraft**

Maximum Altitude: 349,700 ft (SL-8)

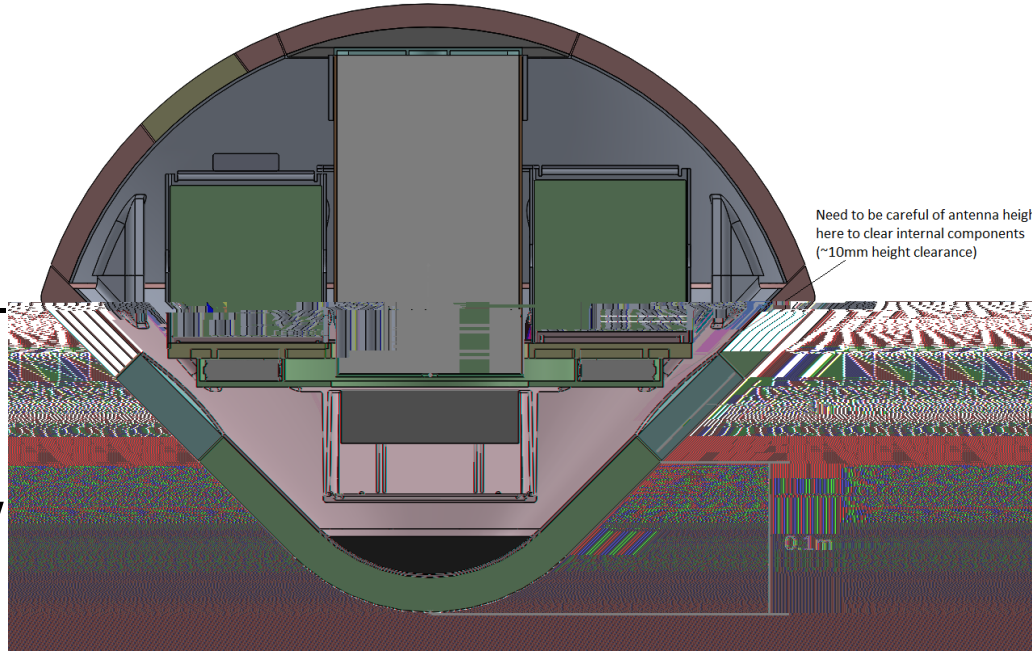
Parameter	Specification
Length	5.75” (14.6 cm)
Width	2.5” (6.35 cm)
Height	2.5” (6.35 cm)
Weight (UBR board, daughter board, GPS, battery, and enclosure)	790 g (27.9 oz)
Weight (cables, antennas, etc.)	85-300g est.
Nominal power Consumption	840mA @ 3VDC
Nominal battery capacity	7.75 Ah

UBR-ERAU Advanced ADS-B Transmitter for sRLVs

Upgraded firmware and GPS hardware

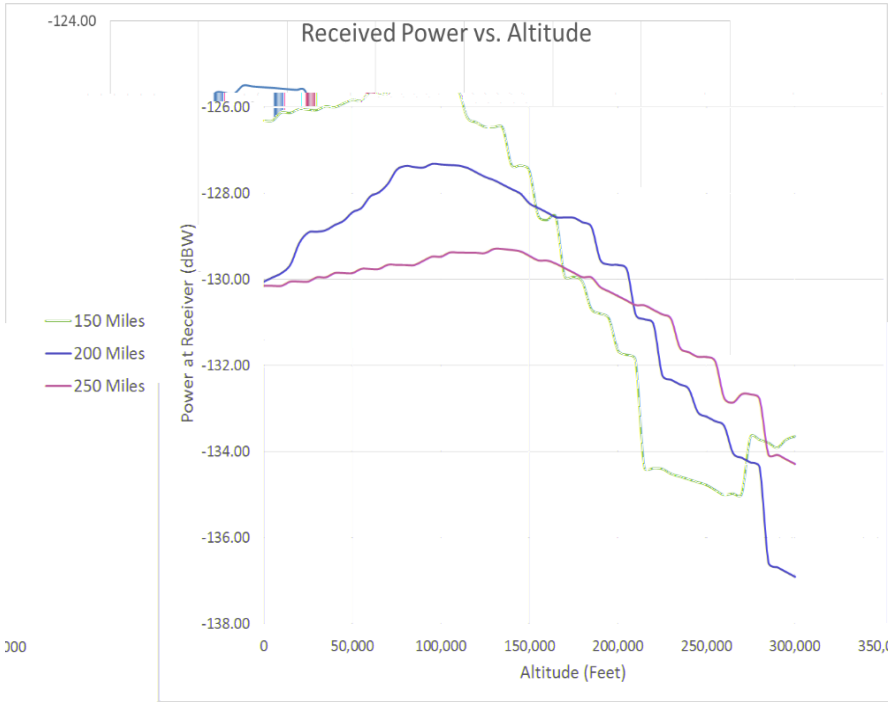
Terminal Velocity Aerospace

- Integration of Advanced ADS-B Unit onboard reentry vehicle
- Funded by NASA Ames
- Goals:
  - Evaluate performance of ADS-B broadcasting through experimental TPS material
  - Demonstration of UBR on new vehicle type



Link Budget Analysis

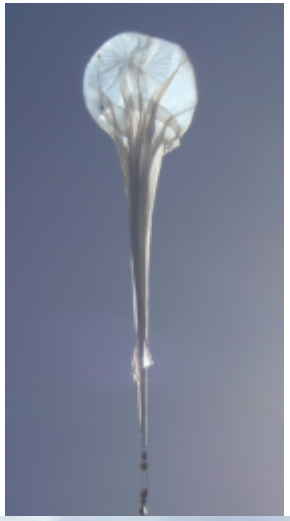
Link Budget ADS-B				
	Symbols	Data	Units	Deviation
Frequency	f_0	978	MHz	0.3125
Wavelength	λ	0.30654	m	0.000006
Modulation Rate	B	1.041667	Megabits/sec	
Altitude	h	45.72	km	
Distance	d	241.4	km	
Offset Angle	Θ	10.72	degrees	
	Symbols	Gain/Loss	Units	Equation
Transmitter	P_{TX}	8.5	dBW	
Transmitter Cable	L_{TX}	0.9	dB	
Transmitter Antenna	G_{TX}	4.6	dBi	
TPS Window	L_M	0	dB	Not Disclosed
Free Space	L_{FS}	140.1	dB	FSPL=20 log_10[(4*π/C)*f_0*d]
Pointing Loss Tran		1.0	dB	
Pointing Loss Rec	L_P	1.0	dB	
Polarization Loss	L_H	3.0	dB	
Receiver Antenna	G_{RX}	7.0	dBi	
Receiver Cable	L_{RX}	0.9	dB	
Signal Present at	P_{RX}	-123.8	dBW	
Receiver		-126.8	dBW	
Margin		-2.8	dBW	
		-5.8	dBW	



Amplification needed with TPS material added as altitude is increased.
Note: TPS material unknown and not included in models shown.

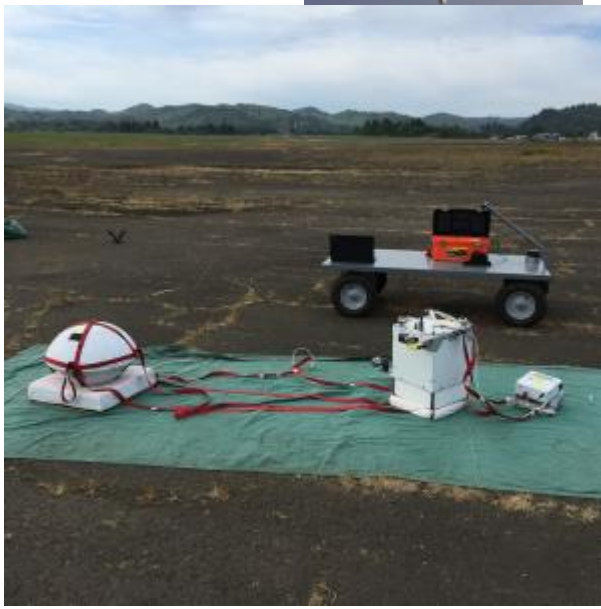
Terminal Velocity Aerospace Reentry Vehicle
Drop from stratospheric balloon

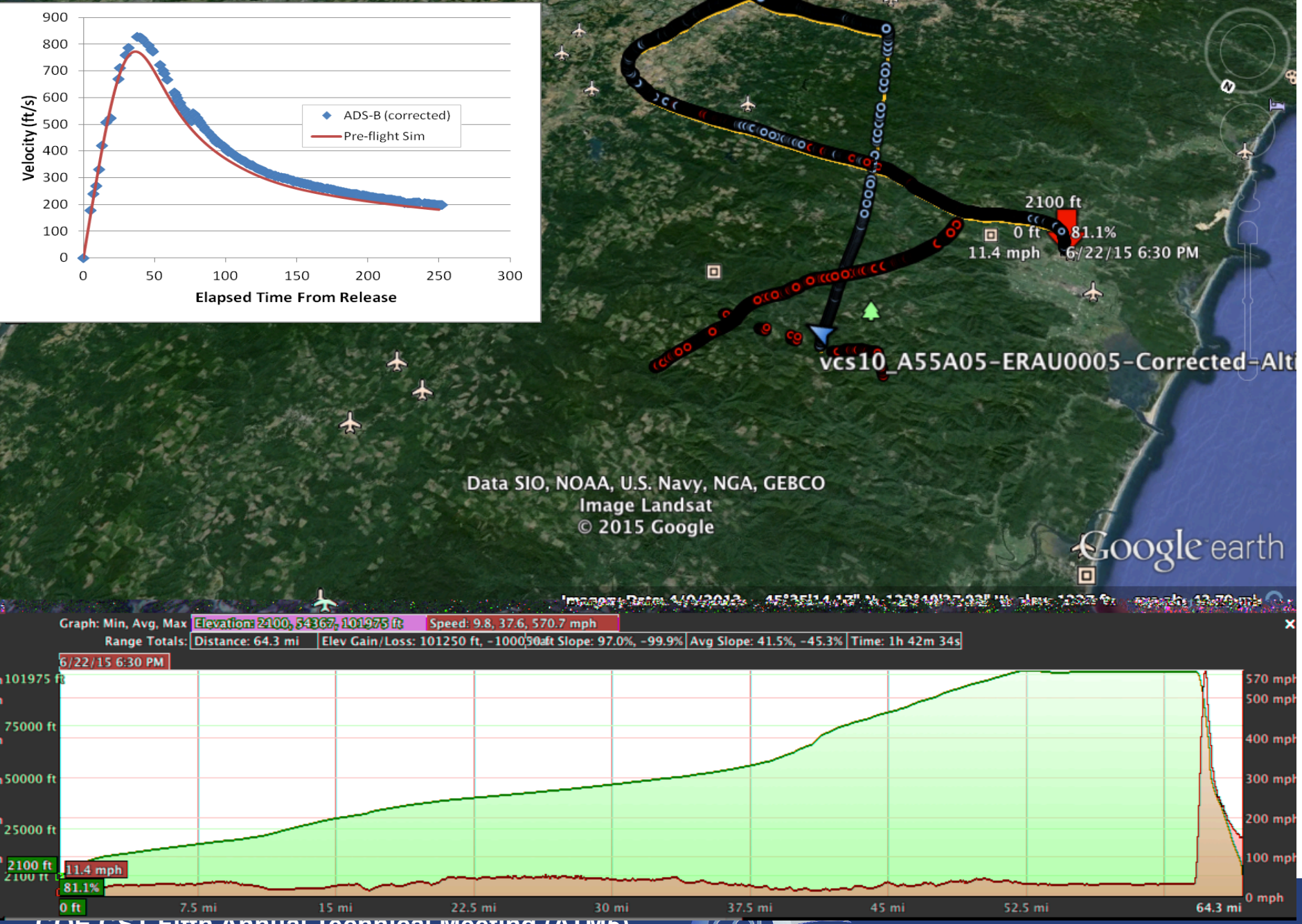
Terminal Velocity Aerospace Reentry Vehicle
Drop from stratospheric balloon



- Dropped from 100Kft - ADS-B payload reported at 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 flight with
  - ADS-B on both balloon and ballistic payload
  - Tranmission through heat shield




Velocity (ft/s)
900
800
700
600
500
400
300
200
100
0
0
50
100
150
200
250
300
Elapsed Time From Release
ADS-B (corrected)
Pre-flight Sim
2100 ft
0 ft
81.1%
11.4 mph
6/22/15 6:30 PM
vcs10_A55A05-ERAU0005-Corrected-Alti
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
© 2015 Google
Google earth
Graph: Min, Avg, Max
Elevation: 2100, 54367, 101975 ft
Speed: 9.8, 37.6, 570.7 mph
Range Totals:
Distance: 64.3 mi
Elev Gain/Loss: 101250 ft, -100050 ft
Slope: 97.0%, -99.9%
Avg Slope: 41.5%, -45.3%
Time: 1h 42m 34s
6/22/15 6:30 PM
101975 ft
75000 ft
50000 ft
25000 ft
2100 ft
11.4 mph
81.1%
0 ft
7.5 mi
15 mi
22.5 mi
30 mi
37.5 mi
45 mi
52.5 mi
64.3 mi
570 mph
500 mph
400 mph
300 mph
200 mph
100 mph
0 mph

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
- Conduct research to address issues with current ADS-B message standards as no message type for space vehicle yet developed / approved.

Planned Future Commercial Space Flights with Experimental ADS-B Payloads

- Near Space Corporation's High Altitude Shuttle System
  - Surrogate winged suborbital vehicle performing a descent into NAS (from above 60, 000 feet) - ASAP
- SL-11 reflight with GPS through boost phase (16Gs for 12 seconds with FOP – Spring 2016
  First time to pull high-g's with live data
- TVA vehicle –upgrades proposal developed
- Large amateur rocket to >100 miles in consideration
- SL-12 mixed airspace demo with UAS TBD
- Virgin Galactic SpaceShip 2 (TBD)

Source: Near Space Corporation

Planned Future Commercial Space Flights with Experimental ADS-B Payloads

Source: Near Space Corporation

- Expendable Launch Vehicle
  - Currently in planning stages for first stage
  - fly back booster
  - expendable

- 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.

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