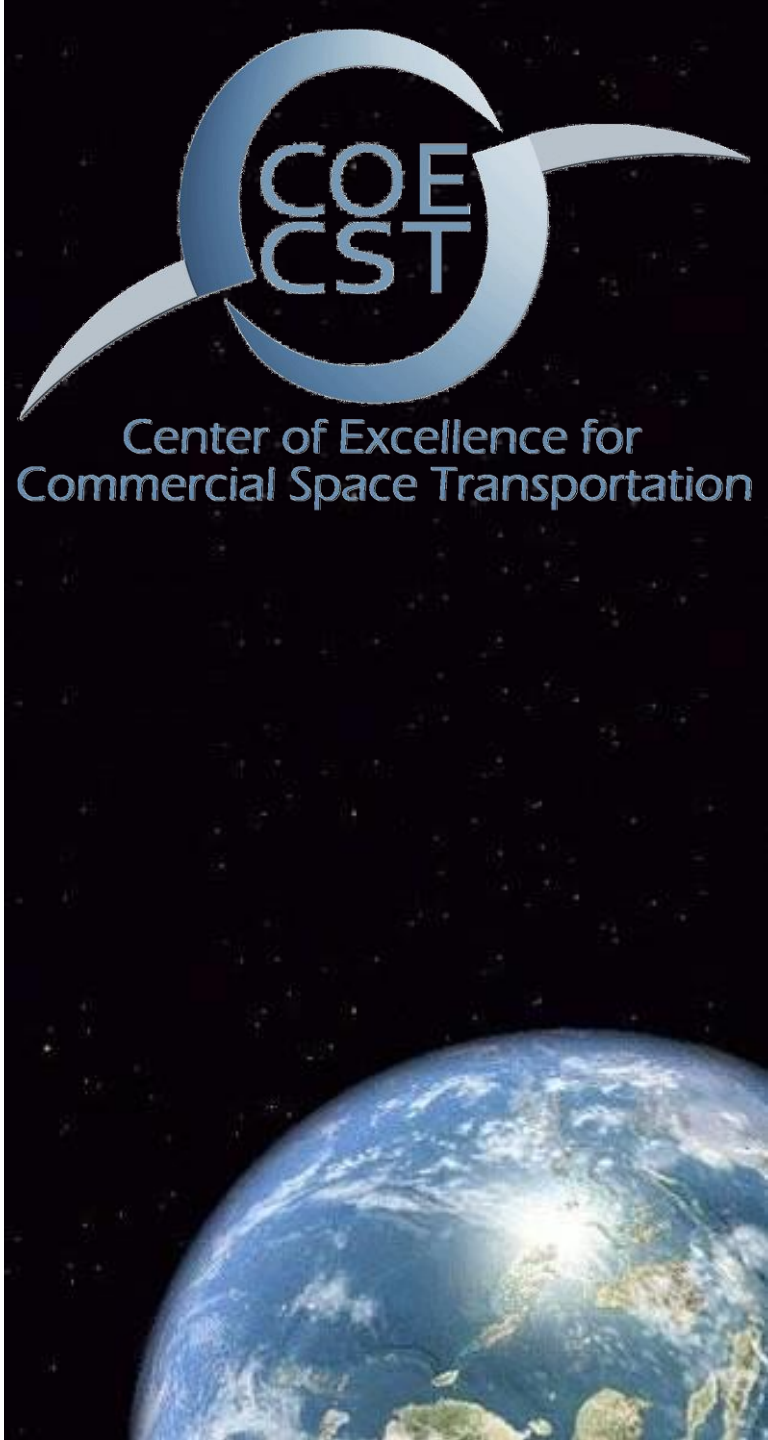
COE CST Third Annual Technical Meeting:

Development and Demonstration of an ADS-B Prototype for Reusable Launch Vehicles

Richard S. Stansbury

30 October 2013



Overview

- Team Members
- Purpose of Task
- Research Methodology
- Results or Schedule & Milestones
- Next Steps
- Contact Information

Team Members

- PIs: Richard S. Stansbury and Massood Towhidnejad
  - Embry-Riddle Aeronautical University
  - Next Generation Embry-Riddle Advanced Research Laboratory (NEAR)
- Students:
  - Dominic Tournour, BS Software Engineering
  - Dylan Rudolph, MS in Electrical and Computer Engineering
- Research Partners
  - Nick Demidovich, FAA AST, FAA Project Lead
  - Jon Dinofrio, FAA WJHTC
  - Chuck Greenlow, FAA WJHTC
  - David Edwards, MITRE Corp.

Purpose of Task

- Support of suborbital reusable launch vehicles (sRLVs) for commercial space transportation requires considerations for safe integration into the national airspace system (NAS)
  - Airspace sterilization
  - Greatest uncertainty during descent under parachute
- ADS-B technology has been used for situational awareness for pilots and air traffic management
  - Provides tracking capability within the NAS
  - Limitations exist beyond the NAS
    - Altitude limits (e.g. 101,337.5 ft under UAT specification)
    - Vertical velocity limits (roughly 320 knots under UAT)
    - GPS limits (ITAR restricts, < 1,000 knots and < 60,000 ft)
- This research presents the adaptation of existing ADS-B technology to support operation for sRLVs exceeding current technology limits

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
  - 2009 Red Glare VII (amateur rocket)
  - 2010 AFRL research balloon
  - 2010 NASA Wallops sounding rocket
  - 2012 Up Aerospace Spaceloft VI
  - Manifest for 2013 Spaceloft VII flight

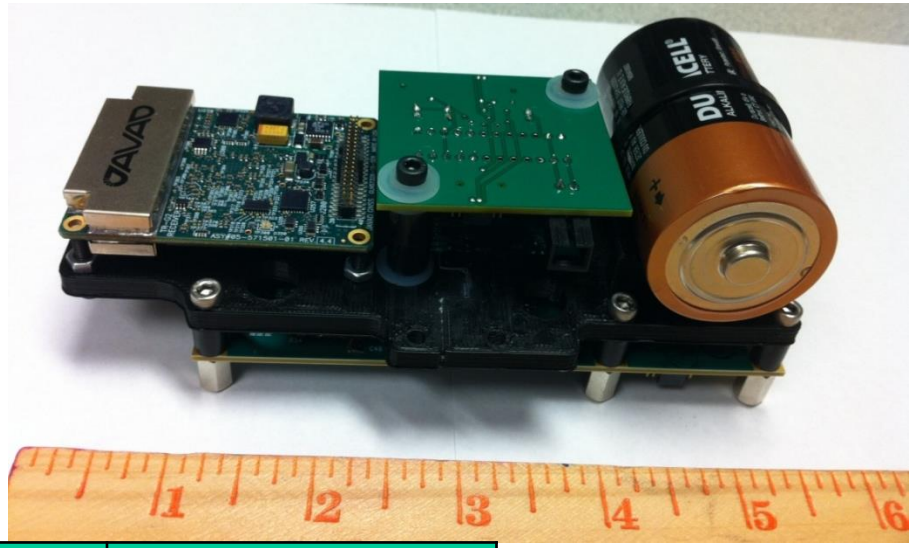
MITRE®
TECHNOLOGY APPLIED

Technical Issues

- MITRE recommended an adaptation of the existing design and software to develop an advanced UBR capable of supporting use onboard sRLVs
  - Upgrade GPS to exceed ITAR limits
    - 60,000 ft
    - 1,000 knots
  - Upgrade firmware
    - Support binary protocol of new GPS
    - Address altitude limit
  - Ruggedization
    - Mil-spec equivalent components
    - New enclosure

Hardware Upgrades

- GPS: Javad TR-G2 w/ space velocities enabled
- Daugherboard: power regulation, TTL-to-RS232, connectivity
- Battery: SAFT LO-26SX (3VDC)
- UBR Board: Replaced numerous components with Mil-spec equivalents
- UAT Antennas
  - Ballon: Antcom 978MHz antenna (stub)
  - Rocket: UB Corp. 978MHz blade antenna
- Ruggedization:
  - Enclosure constructed to house new unit
  - Epoxy potting of potentially shock-and-vibe sensitive components
  - Thermal issues including both heating and cooling must be addressed for each platform
  - Ecosorb EMI/RFI isolation material used to line enclosure



	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

Software Upgrades

- Reuse of MITRE software for the UBR-TX board
- **GPS software parser**
  - Previously, parsed SiRF binary protocol
  - Replaced with Javad GREIS message parsers
  - Unit conversions between Javad data output to UAT required data
- **Maximum altitude**
  - Ideal approach: utilize part of the reserved message space to increase bit size beyond 12-bits
    - Not parsed by current GBT data feeds
  - Interim approach: “roll-over” altitude once it exceeds altitude limit

Results or Schedule/Milestones

- Flights funded under NASA Flight Opportunities Program AFO1 and AFO5

- Near Space Corporation Nano Balloon System (NBS), 22 Jan 2013
  - Achieved altitude near 59,000 ft

- NSC NBS Flight #2, 15 Feb 2013
  - Achieved altitude near 94,000 ft
  - Details on next slide

- NSC, High Altitude Shuttle System
  - Achieved altitude near 106,000 ft

- Up Aerospace, Space Loft 8, 12 Nov 2013

NSC NBS Flight Details, 15 Feb 2013

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

Additional Flight Details

- Terrain had a major impact on ability to track unit at launch and recovery sites
- Minimum temperature (courtesy of NSC) inside foam container was -20.6 degrees C
- Timing accuracy indicated no uncompensated clock drift (most data points fall within +/- 1us of UAT specs)
- Emitter category 15 (space/trans-atmospheric vehicle) data is not smoothed resulting in “noisy” vertical rate information
- ITT Exelis system current features a 300 NM cap, which prevented an adequate analysis of achievable range

Next Steps

- Upcoming Flights
  - 12 Nov 2013, Up Aerospace Spaceloft 8
  - TBD Spring 2014, Up Aerospace Spaceloft 9
  - Looking into additional opportunities
- Future engineering developments
  - Ability to boost power for higher altitude performance (e.g. satellite or International Space Station)
  - Transition toward DO-282B to “go to glass”, i.e. visible to currently equipped aircraft
  - Address high altitude and velocity limits via reserved message

Contact Information

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  Electrical, Computer, Software, and Systems Engineering Department

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  Daytona Beach, FL 32137
- Email: richard.stansbury@erau.edu
- Phone: 386-226-7923

BACKUP SLIDES

Test and Demonstration Plan

- **FAA William J. Hughes Technical Center**
  - GNSS simulator testing
    - Balloon flight simulation
    - Sounding rocket simulation
  - Field support
- **NASA Flight Opportunities**
  - AFO-1 (flown)
    - NSC Nano Balloon System
  - AFO-5 (approved)
    - NSC High Altitude Shuttle System (HASS)
    - Up Aerospace SpaceLoft VIII (or future flight)
- Prior to flight onboard a sounding rocket, an amateur rocket (TBD) will be used to test system

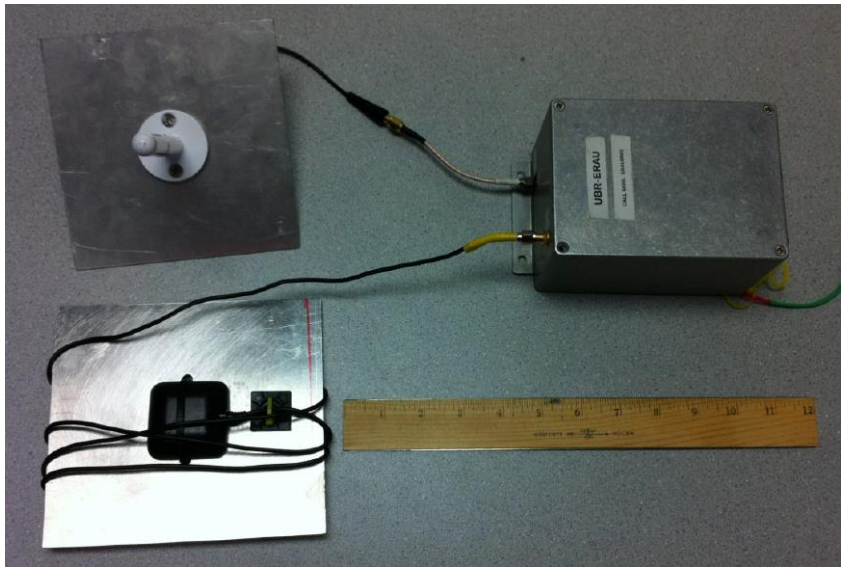
Outline

- Background
- Upgrades of ADS-B unit for suborbital flight
- **High altitude balloon flight testing**
  - Test goals
  - Flight test #1
  - Flight test #2
- Future flights and development

Success Criteria for Balloon Flight

- Successful launch and recovery of UBR-ERAU onboard NSC NBS
- Broadcast ADS-B UAT messages once per second
- Tracking payload via FAA/ITT live data feeds
- Mobile ground-based receiver will assist in filling data gaps near takeoff and recovery
- Payload would achieve an altitude of no-less than 90,000 ft. MSL (mean sea level) in order to demonstrate:
  - Successful operation in near space environment (temperatures and atmosphere)
  - Demonstrate operation at altitudes in excess of the GPS ITAR/COCOM limit of 60,000 ft. MSL

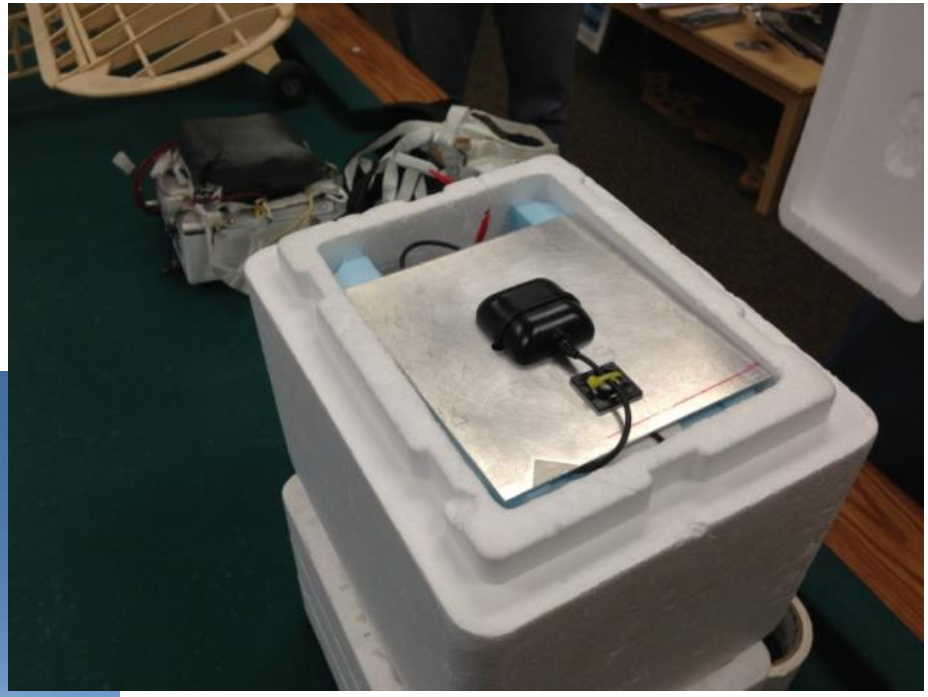
Payload Integration



- Foam enclosure houses payload for NBS
- Internal power via onboard batteries
- Netting material used to secure payload enclosure to balloon and its telemetry unit
- Cable from NBS telemetry unit routed to payload for remote enable/disable capability
  - Telemetry unit also provides position, altitude, and pressure data

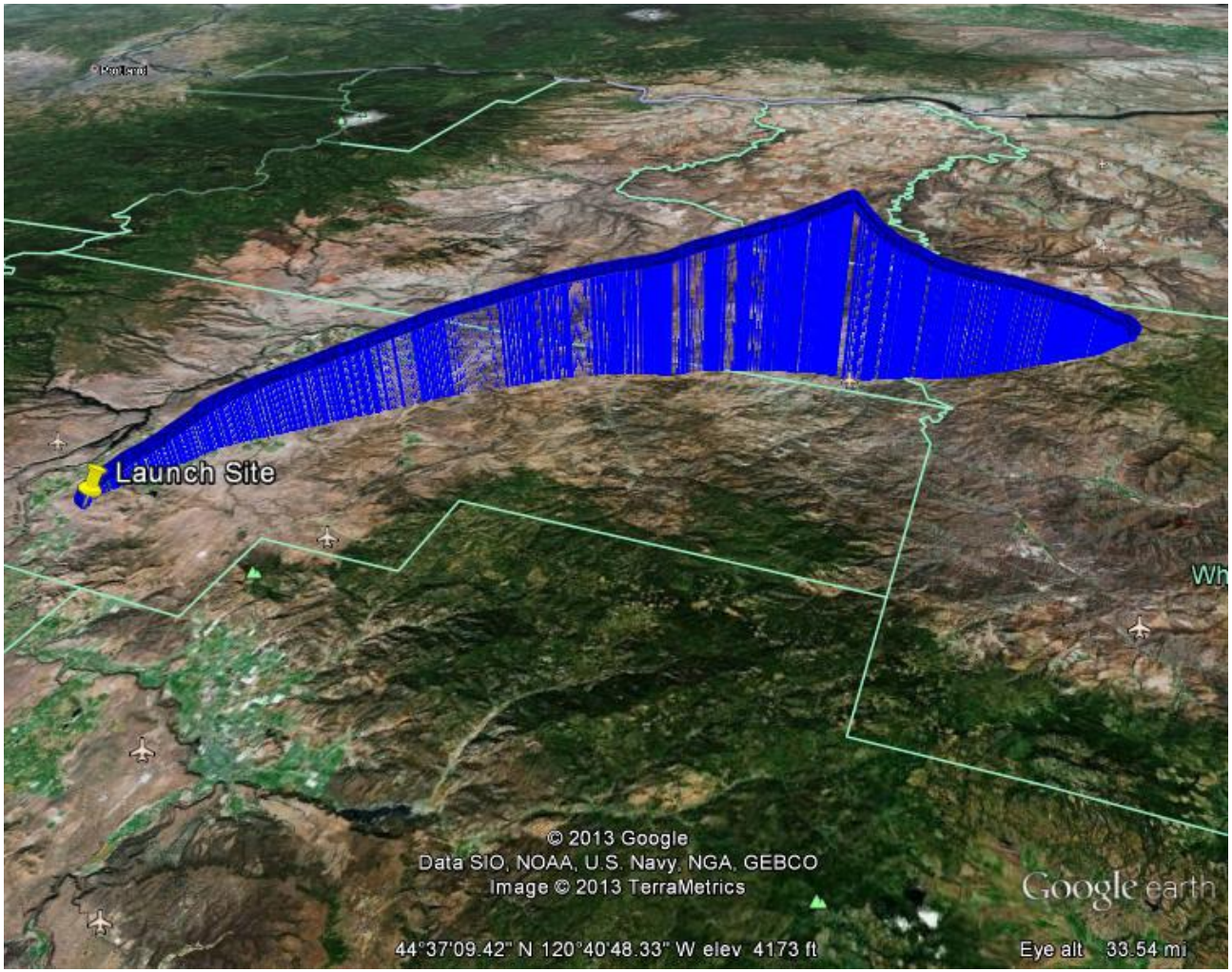
Near Madras, Oregon, January 2013

FLIGHT TEST NUMBER 1



Results from Preliminary Data Analysis

Maximum Altitude (geometric), MSL	59,575 ft
Maximum Altitude (pressure), MSL	59,325 ft
Flight Time – Ascent	63.07 min
Flight Time – Descent	29.33 min
Flight Time – Total	92.40 min
Total Number of Unique GBTs Receiving Data	14
Number of GBTs Tracking at Apogee	8



Flight Track from launch site to recovery site (tracks left to right)

Near Tillamook, Oregon, January 2013

FLIGHT TEST NUMBER 2

Results from Preliminary Data Analysis

Maximum Altitude (geometric), MSL	94,025 ft
Maximum Altitude (pressure), MSL	94,200 ft
Flight Time – Ascent	116 min
Flight Time – Float	58 min
Flight Time – Descent	38 min
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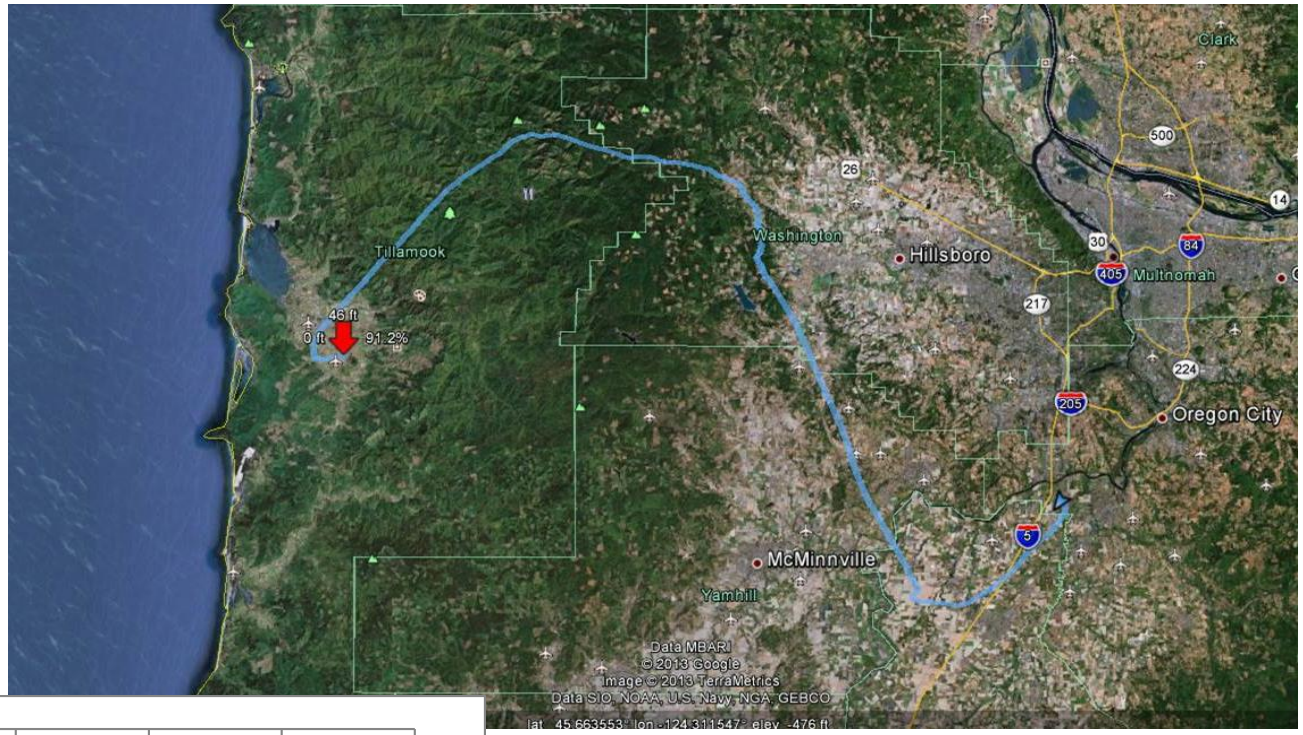
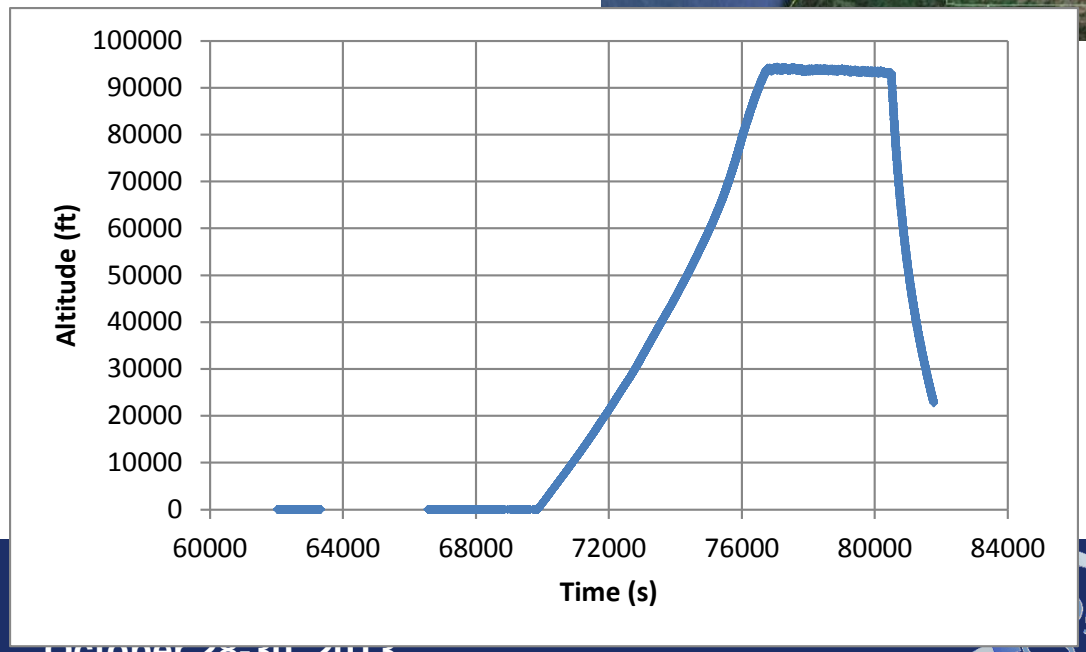

Clark
500
28
14
Washington
Hillsboro
30
84
405
Multnomah
Tillamook
46 ft
0 ft
91.2%
217
224
205
Oregon City
5
McMinnville
Yamhill
Data MBARI
© 2013 Google
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO


Altitude (ft)
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
60000
64000
68000
72000
76000
80000
84000
Time (s)

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