PL&HA Technology

AAS 18-051

COBALT: Terrestrial flight test of landing navigation using Lander Vision System with Navigation Doppler Lidar

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*JMC on IPA detail to NASA Johnson Space Center

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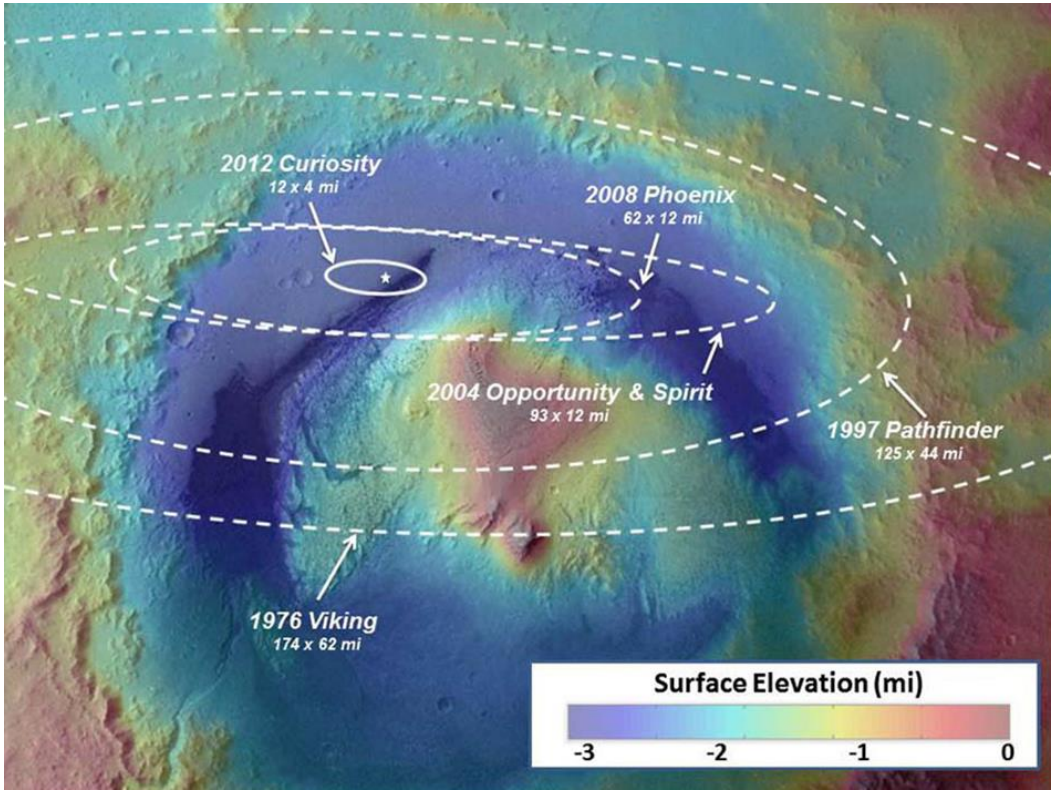
COBALT Motivation

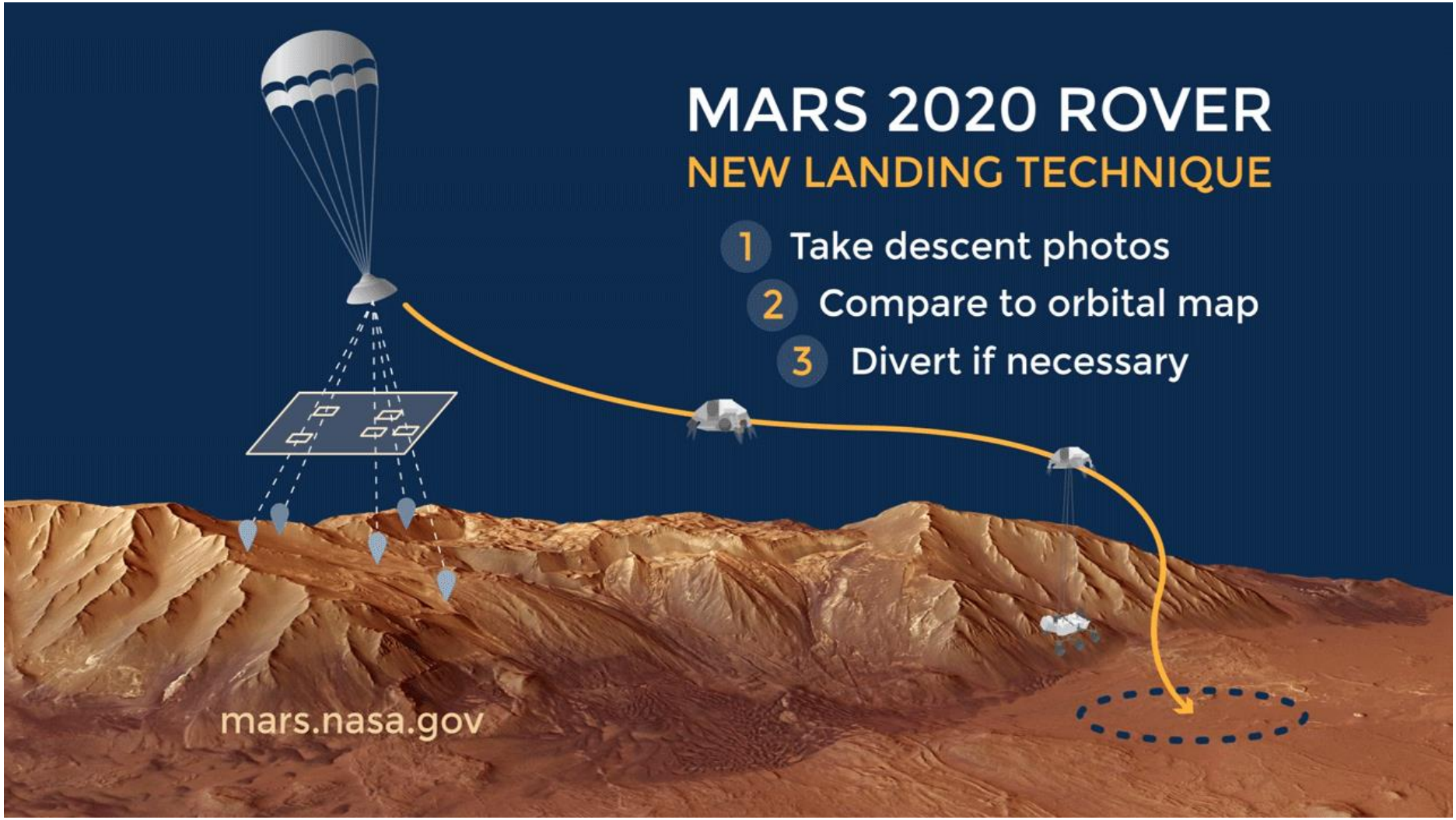
Co**O**perative **B**lending of **A**utonomous **L**anding **T**echnologies

- Part of Multi-program, Multi-center* effort to advance TRL and reduce risk for spaceflight infusion of GN&C Precision Landing technologies
- Applicable to Mars, Moon and other planets and moons (e.g. Europa)



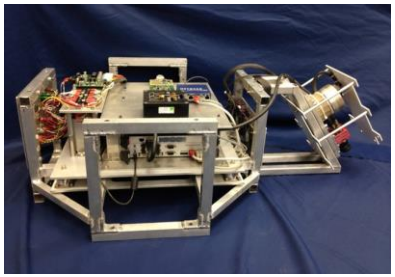
* JPL, JSC, LaRC, AFRC, FO, Masten Space Systems

Mars 2020 – Lander Vision System

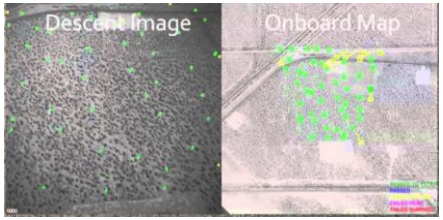


COBALT overview

ADAPT [JPL]



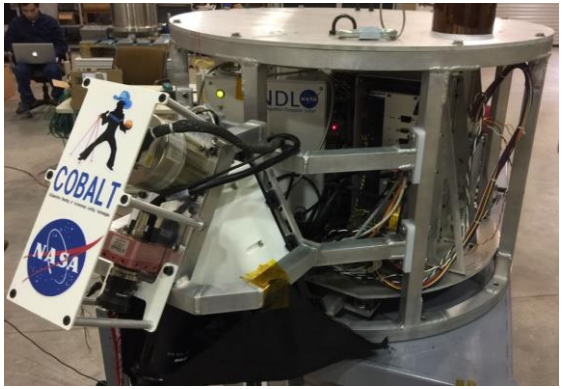
LVS [JPL]



Morpheus/Alhat/NDL

COBALT

Payload



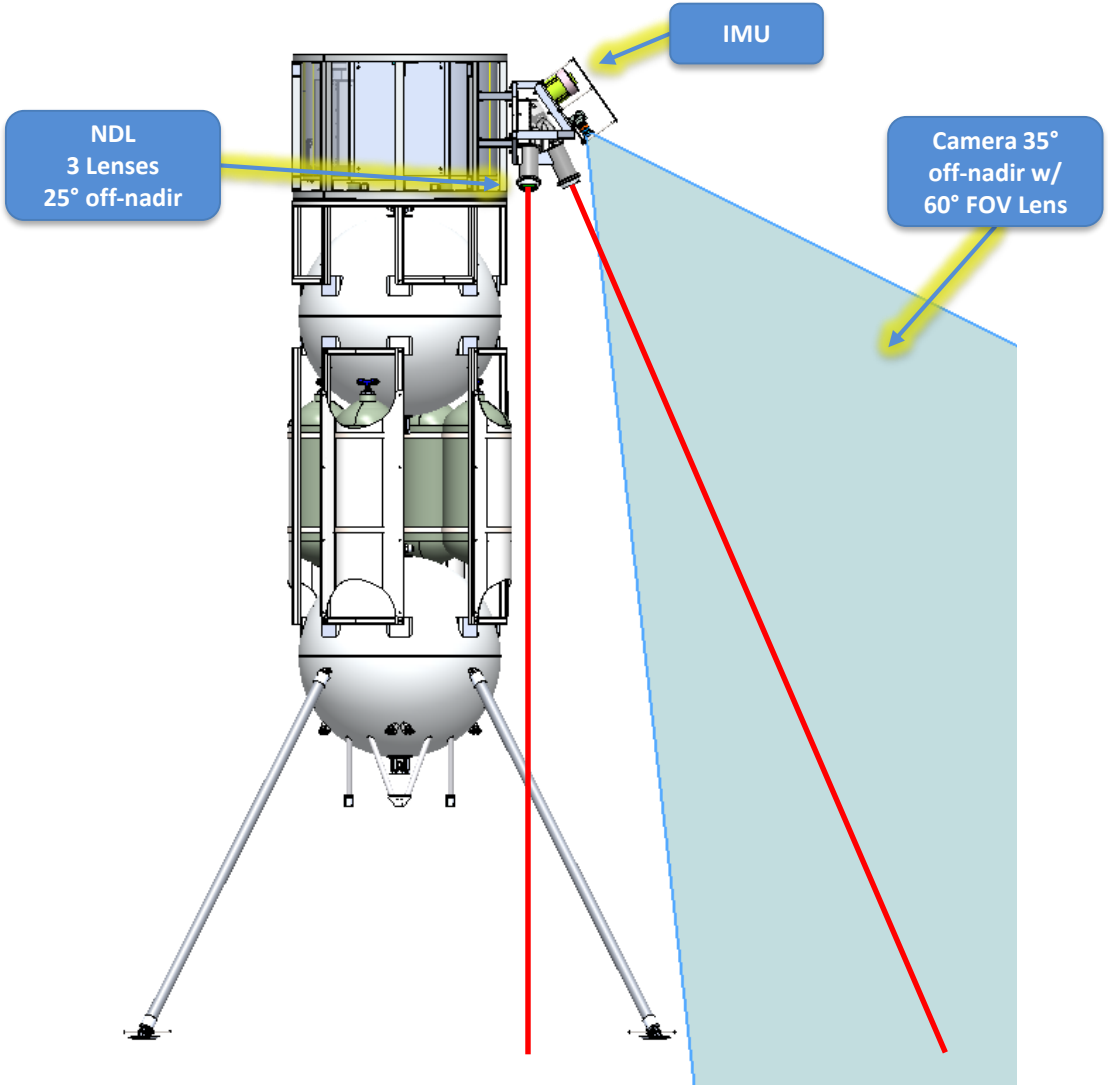
NDL Gen 3 [LaRC]

Open Loop campaign

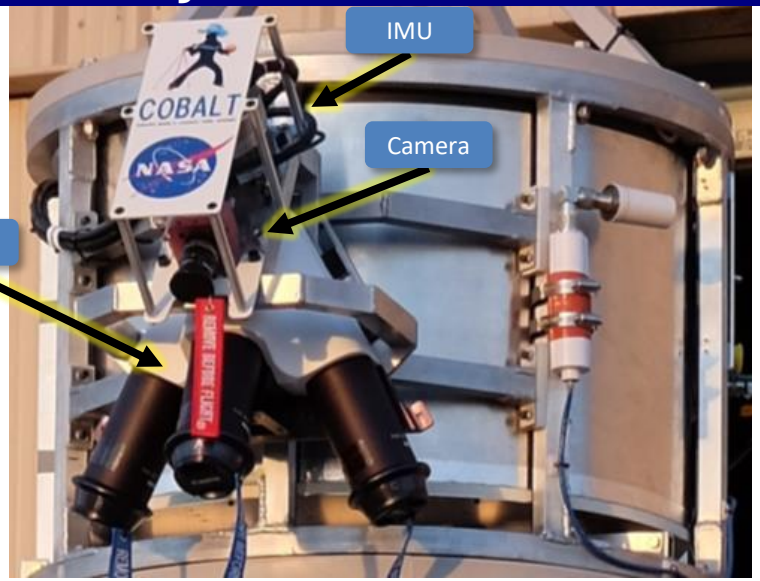
Future

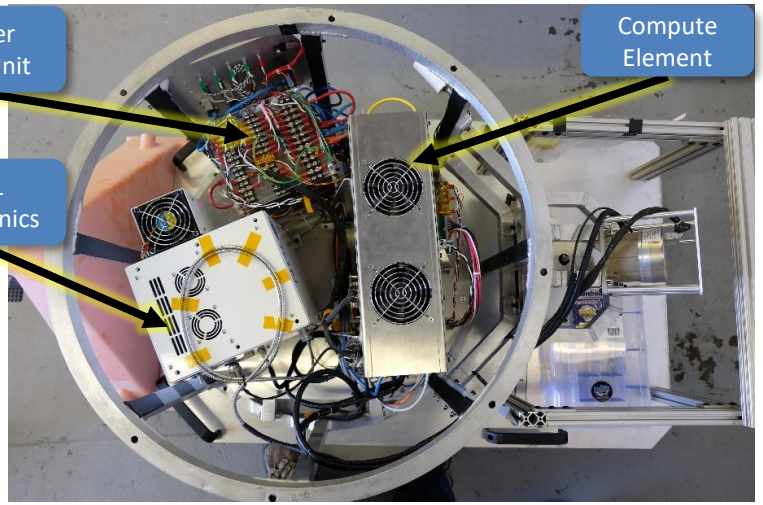
2014 2015 2016 2017 2018

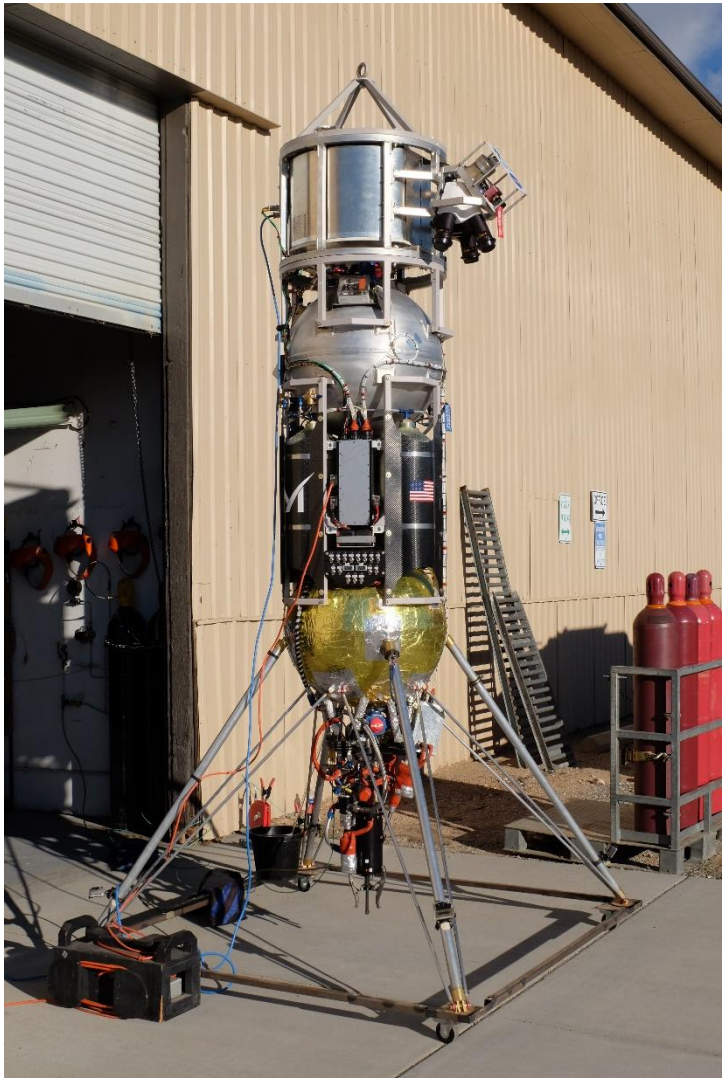
COBALT on Masten Xodiac



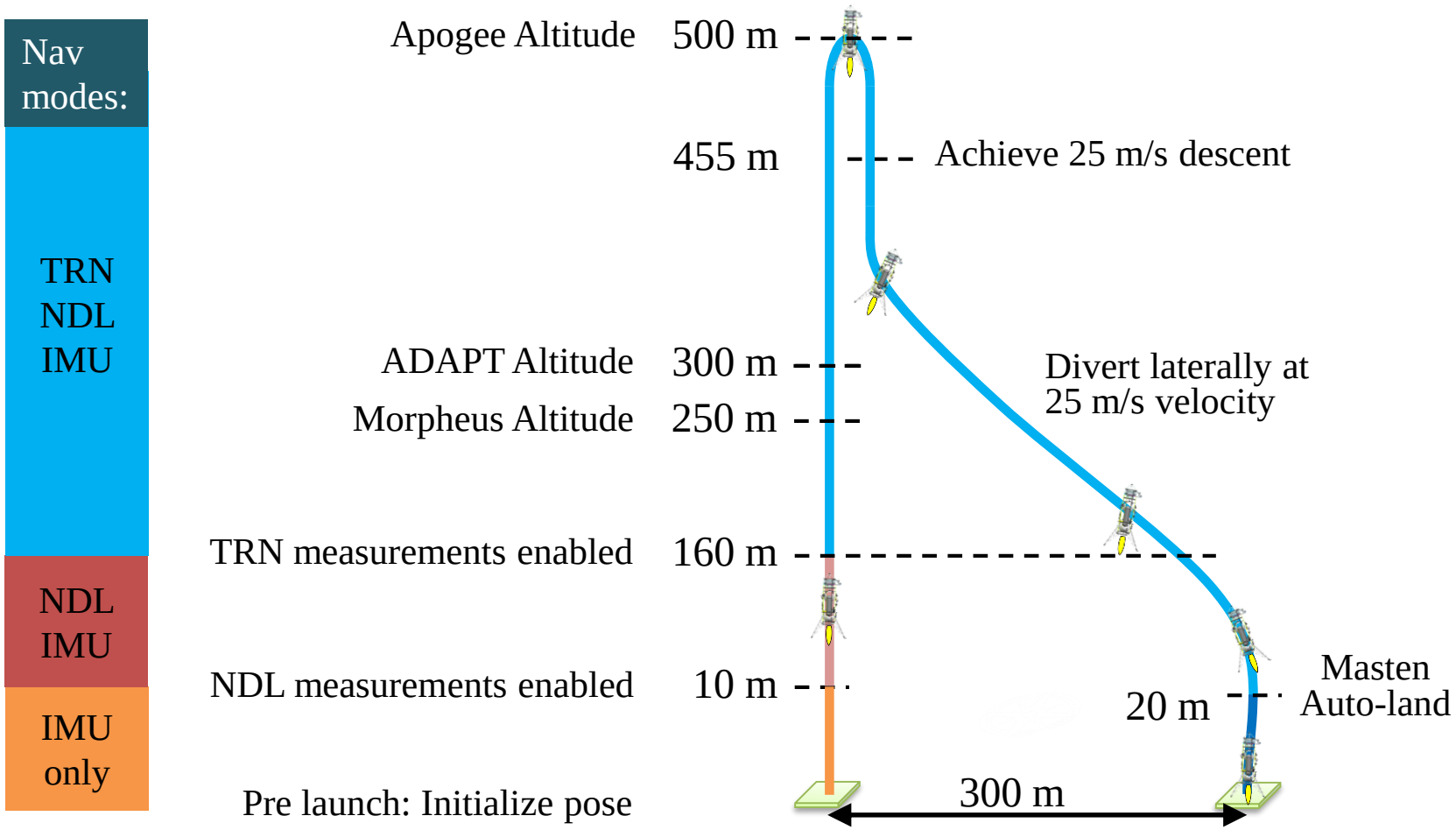
System Architecture







Cobalt Mission Overview



COBALT Navigation Filter

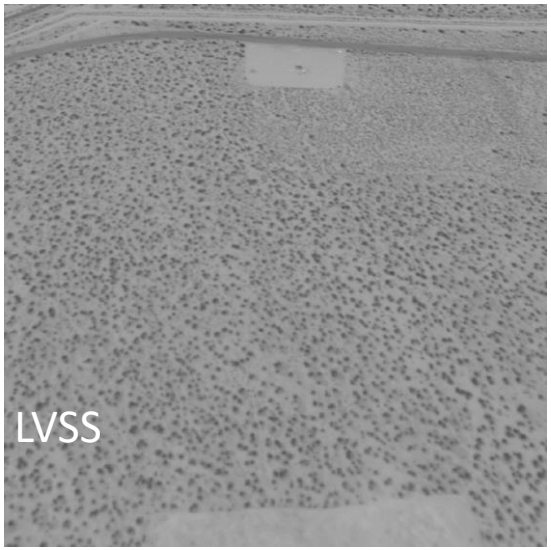
- Based on EKF developed for ADAPT
  - Filter States: pos, vel, att, gyro bias and accel bias
  - LN200 IMU data used for state propagation
  - State updates using LVS image processing
    - 50-100 map-correlated features/image every 1-2 s
- COBALT adds
  - Doppler velocity and range updates from 3-beam Navigation Doppler Lidar (NDL)
    - Range and Doppler velocity at 20 Hz along 3 beams
    - Measurement Editor

COBALT Filter Development

- ADAPT architecture includes Replayer
  - Logs full time-tagged measurement stream (IMU, images, etc) for “replay” through flight software
  - Allows “re-flights” with adjusted parameter settings
- COBALT
  - Developed detailed simulation of NDL sensor
  - Created synthetic NDL data for existing ADAPT flights
    - Allowed Replayer simulation of ADAPT with “synthetic NDL”
  - Used for regression testing throughout development of COBALT filter additions

Replayer + NDL Sim + LVSS

- M2020 Lander Vision System Sim (LVSS)
  - Renders images, creates IMU data along a supplied 6-DOF trajectory
- Extended LVSS to create LVS images, LN200 IMU and NDL data for Replayer sim of full planned COBALT trajectory
  - LVSS toolchain validated using LVSS+replayer re-creactions of adapt FF2 trajectory



Payload Pre-Flight Testing @ JPL

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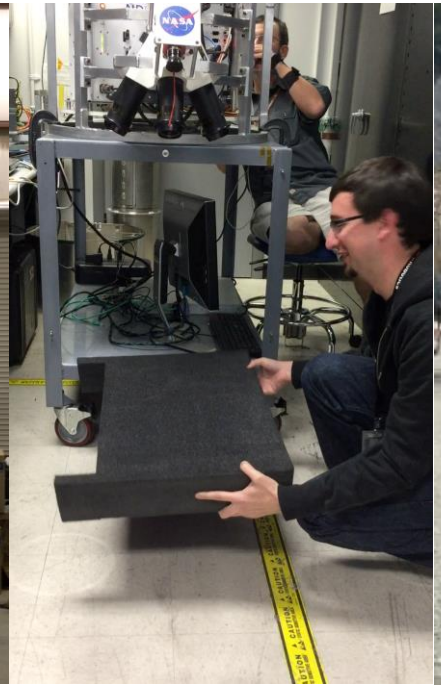
COBALT Project

STMD:GCD / HEOMD:AES-LT / STMD:FO

Swing

Measurement checkout
Payload phasing
Operational run-through

Impact/Timing



Timing characterization between NDL and IMU

ATV

Dynamic testing with GPS
Functional testing of filter
Vibration shake-out
Full system rehearsal

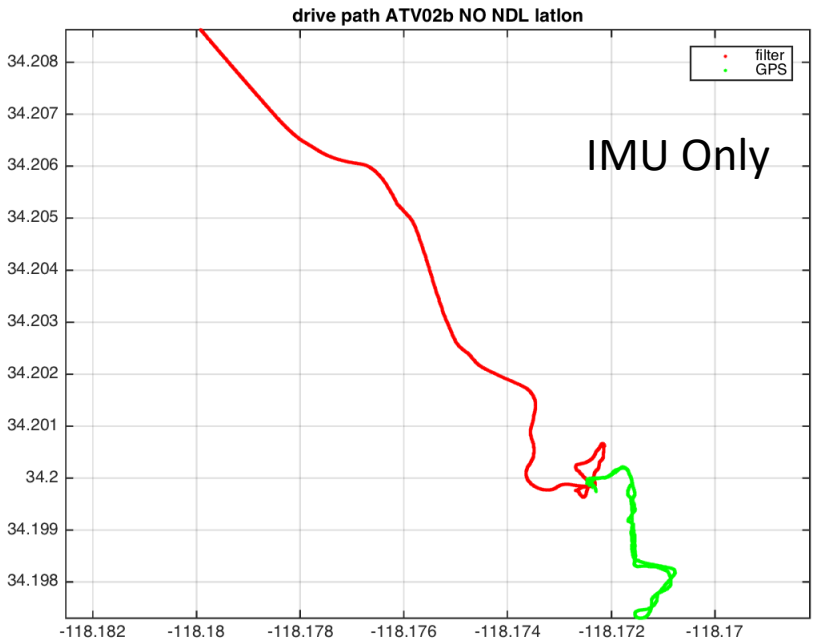
NDL @ JPL

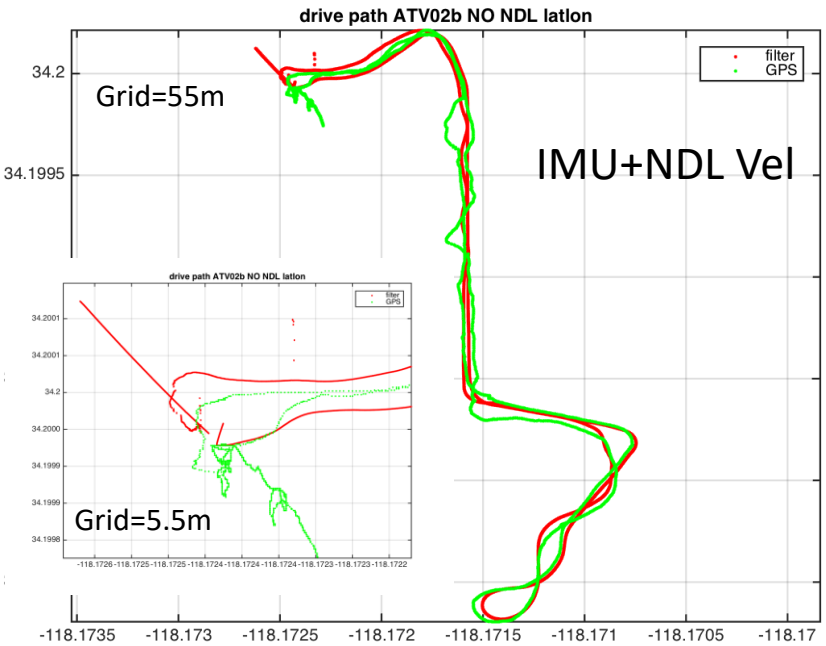
NDL measurements on riverbed at COBALT ranges

ATV02b with/without NDL velocity

- NDL velocity data greatly improves navigation accuracy over IMU-only
  - Prevents run-off caused by accel bias + gravity compensation error

- Filter Data Editor configured to avoid using bad data at low speed
  - Saw data dropouts and outliers at low velocity
  - Replayer run below has low vel/range, 0-data, cond=1, and 3-sigma resid, tests enabled

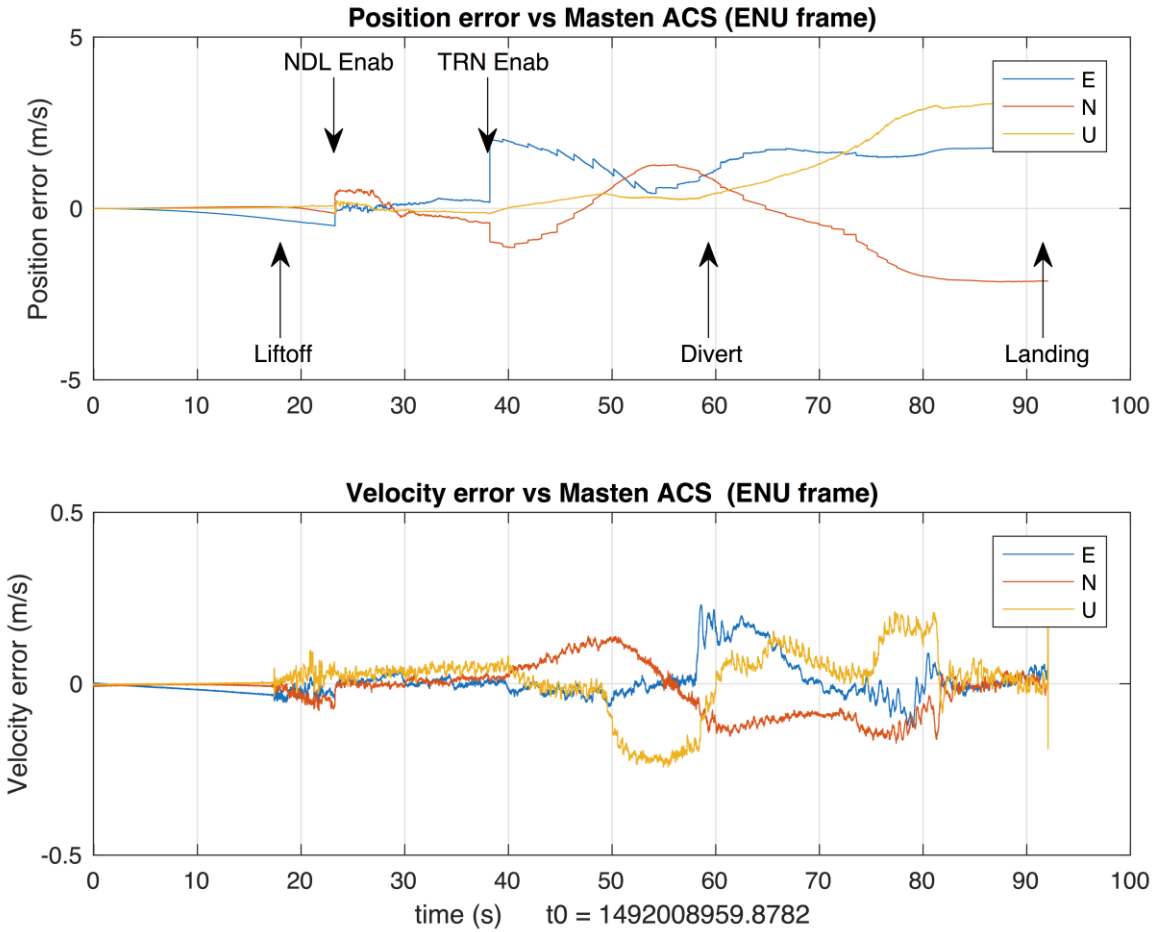




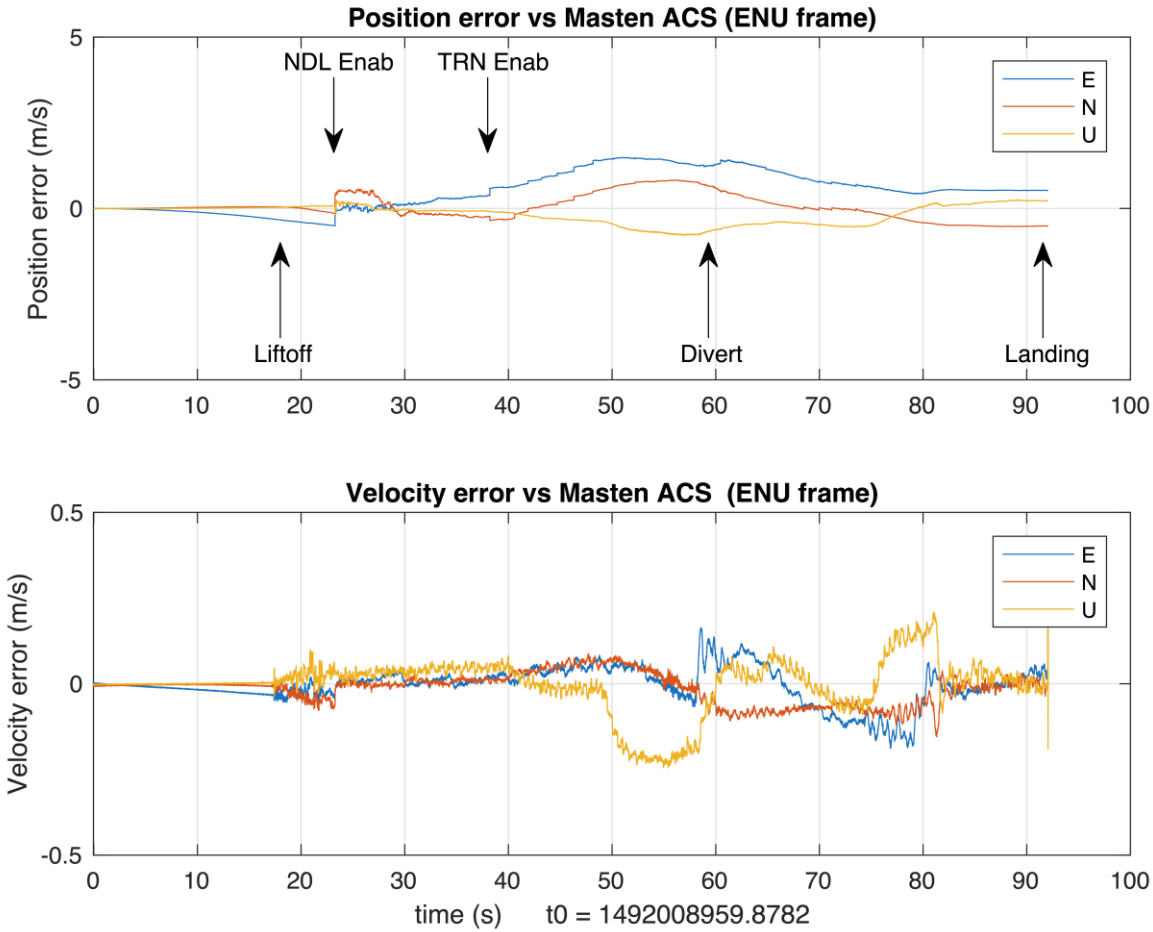
Free Flight

COBALT COL02 Ride Along

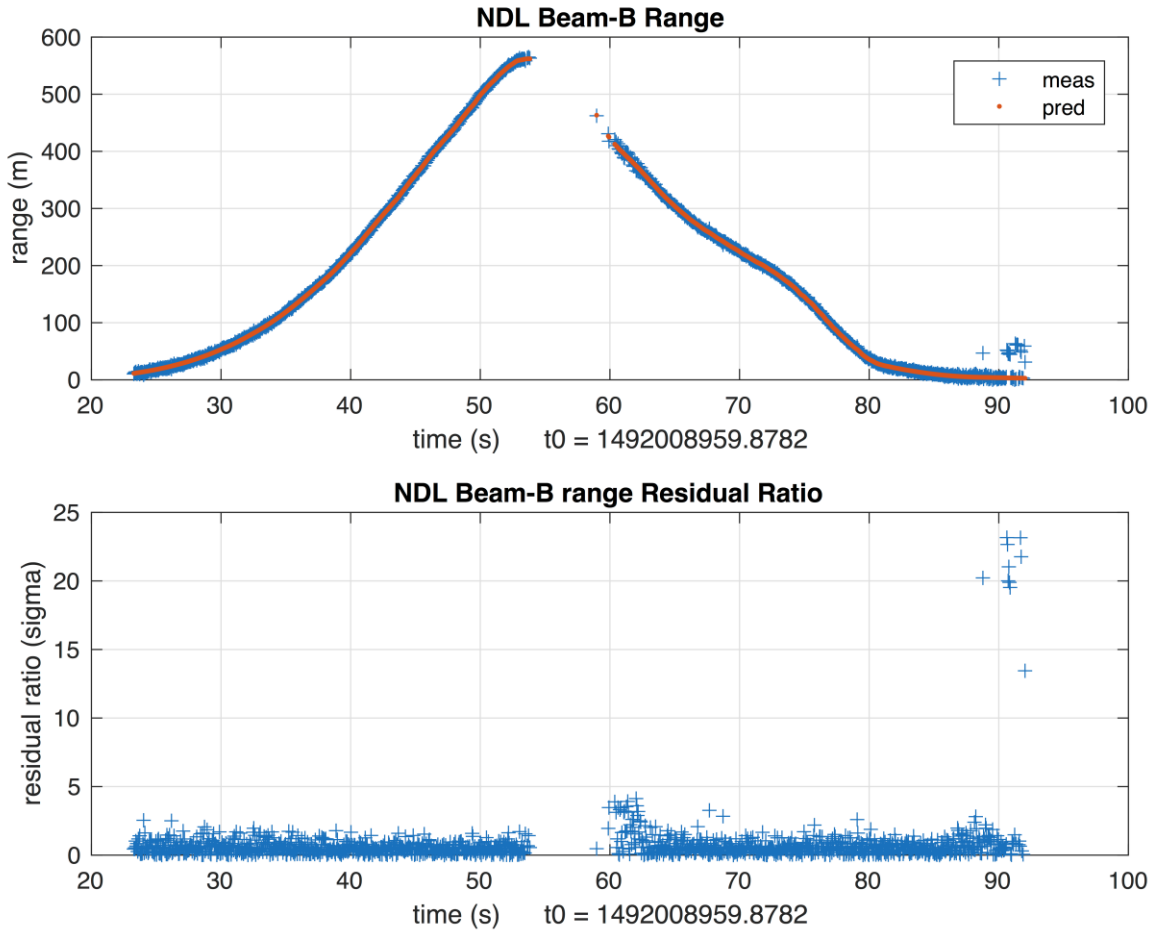
Filter Errors vs Masten ACS



Filter Errors (corrected map-tie, slope)



NDL Range


NDL Beam-B Range
meas
pred
range (m)
time (s)
t0 = 1492008959.8782
NDL Beam-B range Residual Ratio
residual ratio (sigma)
time (s)
t0 = 1492008959.8782

The Team

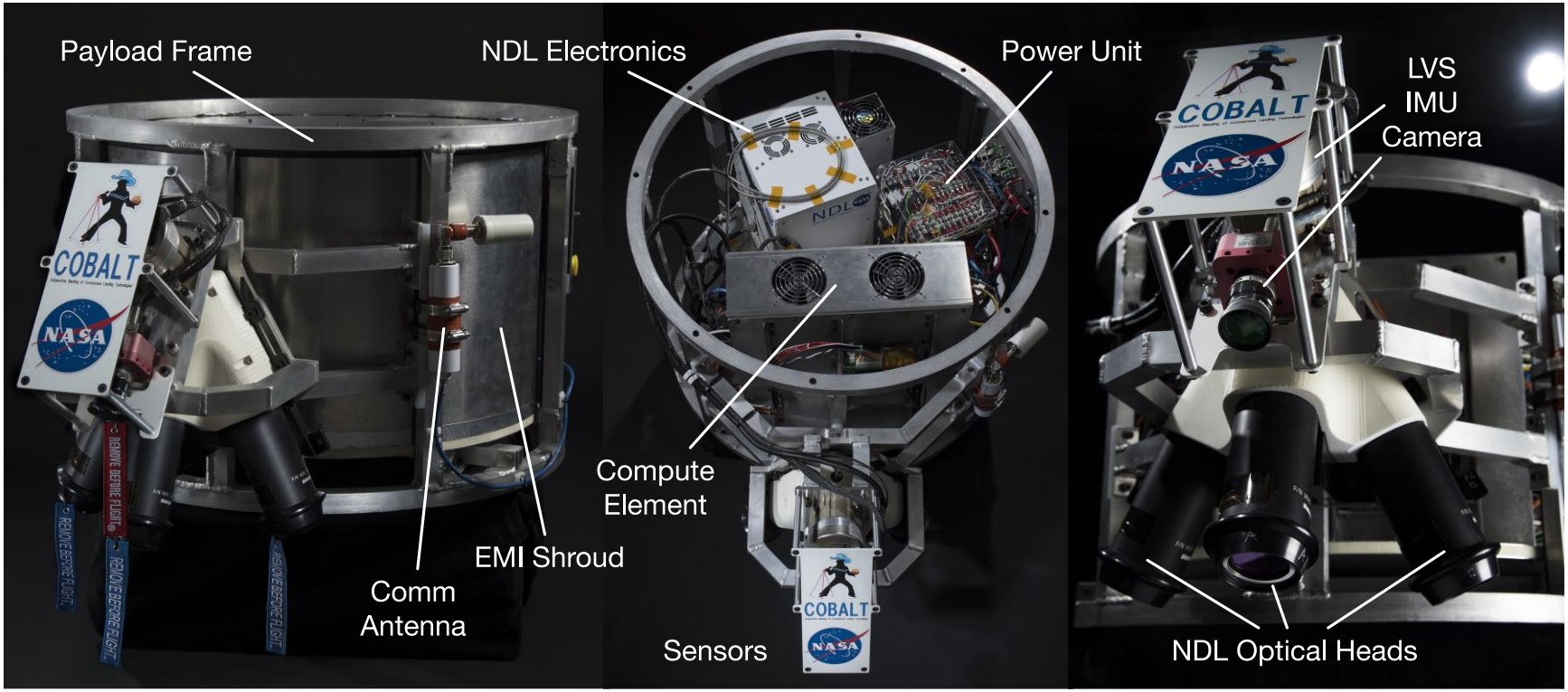
JPL: Carl Seubert, Steve Collins, Ara Kourchians, Carlos Villalpando, Chuck Bergh, Yang Cheng, Jack Dunkle, John Koehler, Matt Shekels, Nikolas Trawny, Seth Aaron
JSC: John Carson, Ronney Lovelace, Megan McCarthy, Carolina Restrepo, Teming Tse

LaRC: Farzin Amzajerdian, Bruce Barnes, Glenn Hines, Diego Pierrottet
Flight Opportunities: Joe Hernandez
Masten: Travis O'Neal, Richard Stelling, Chris Hofman, Reuben Garcia

Free Flight

COBALT

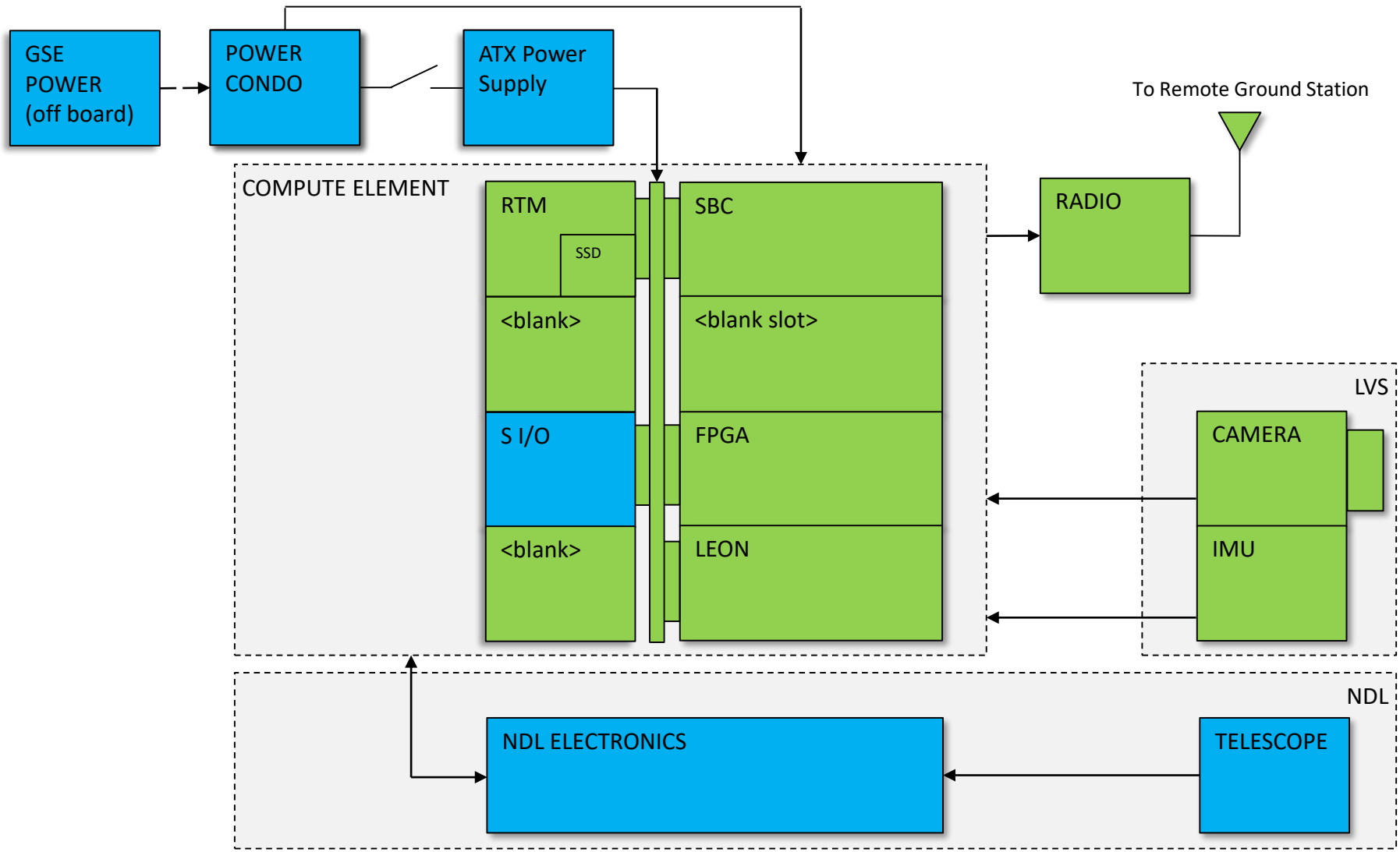
COBALT Project



ATV Testing

ATV Testing

System Architecture



Tethered Flight

COBALT Intro Talking Points

- Technology development program building on the success of NASA's rich history of EDL test programs including ALHAT/Morpheus & ADAPT/Xombie
- Maturing technology not just for Mars, but also going back to moon and even extendable to other planets and moons (eg Europa)
- Multi-center effort – combining the strengths of each center
- COBALT is a reusable platform to test and mature TRL and reduce risk for spaceflight infusion of GN&C landing technologies
- COBALT payload is self contained and could be modified to test different GN&C technologies on different flight test platforms
- Test program and conops designed to maximize flight test envelope of NDL within limits of Xodiac vehicle (which is undergoing flight expansion)
- With JPL's successful history of flight testing TRN on Masten vehicles it was a perfect companion to this NASA flight opportunity funded project