Navigation Doppler Lidar

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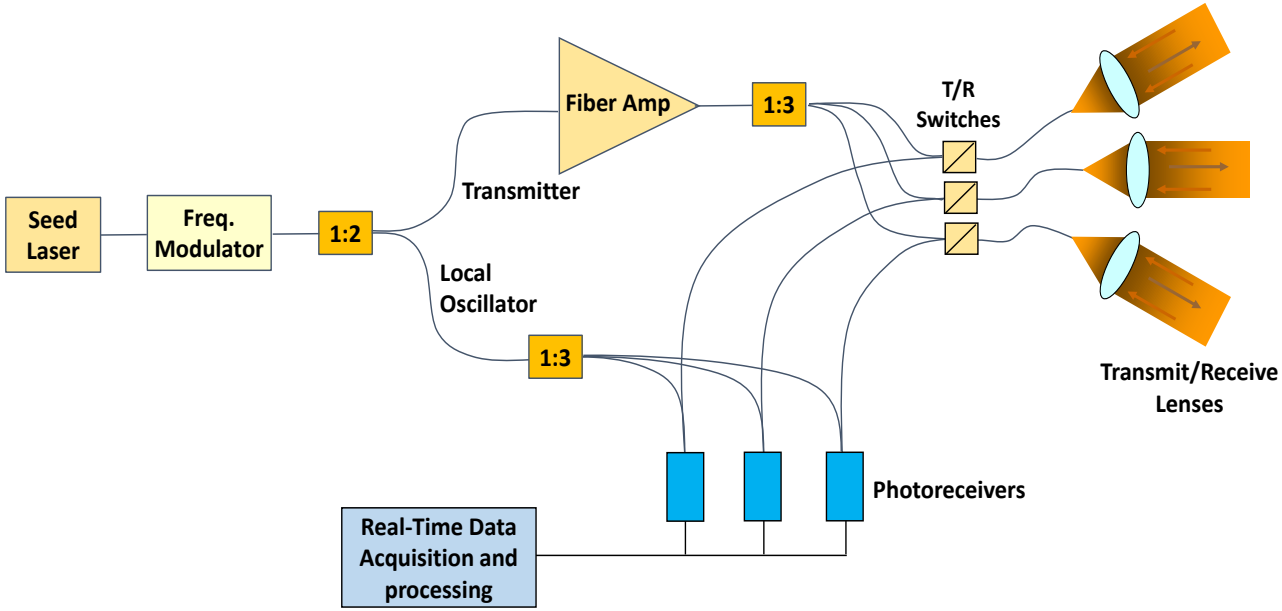
SPONSORS:

- SMD/New Frontiers/Homesteader Program
- HEOMD/AES/Lander Technologies Project
- STMD/Fight Opportunities Program

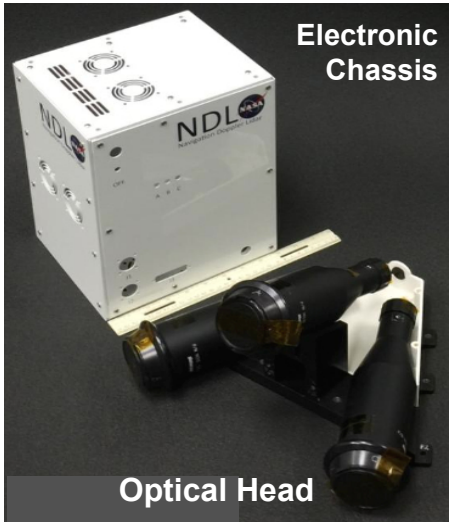
COBALT

Navigation Doppler Lidar (NDL)

- The NDL is a laser-based sensor capable of providing the necessary velocity and altitude measurements for planetary landing
- NDL Measures velocity and range along three different laser beams
- Simultaneous line-of-sight measurements are used to determine:
  - Velocity Vector (V)
  - Altitude relative to local ground (No IMU data required)



GEN 3 NDL

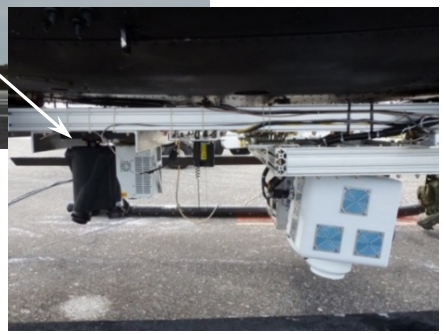


NDL Offers New Capabilities for Planetary Landing Missions

- GPS-deprived environment of space requires onboard sensors for vehicle position and velocity data (past landing missions used radars)
- NDL is a viable replacement for obsolete radar sensors
  - No current spaceflight-qualified COTS velocimeters following Mars Insight landing (using a spare Mars Phoenix sensor)
- NDL offers an order of magnitude higher precision than microwave radars and much higher data quality (low false alarms) while reducing required size, mass, and power
- NDL enables ***"well-controlled"*** descent, landing, and ascent maneuvers to within a few cm/sec
  - Reduced touchdown impact loads ⇨ ***lower lander mass***
  - Optimized fuel consumption ⇨ ***lower mass and risk***
- NDL enables ***"precision navigation"*** to the designated landing location

NDL can enable higher performance, lower risk, and lower cost landing capabilities

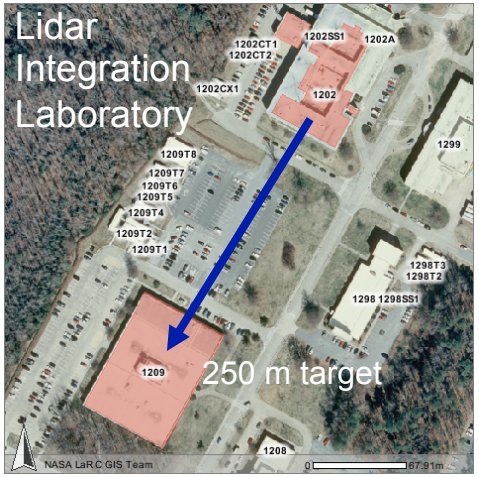
Extensive NDL Test History



Truck Tests

Gantry Tests

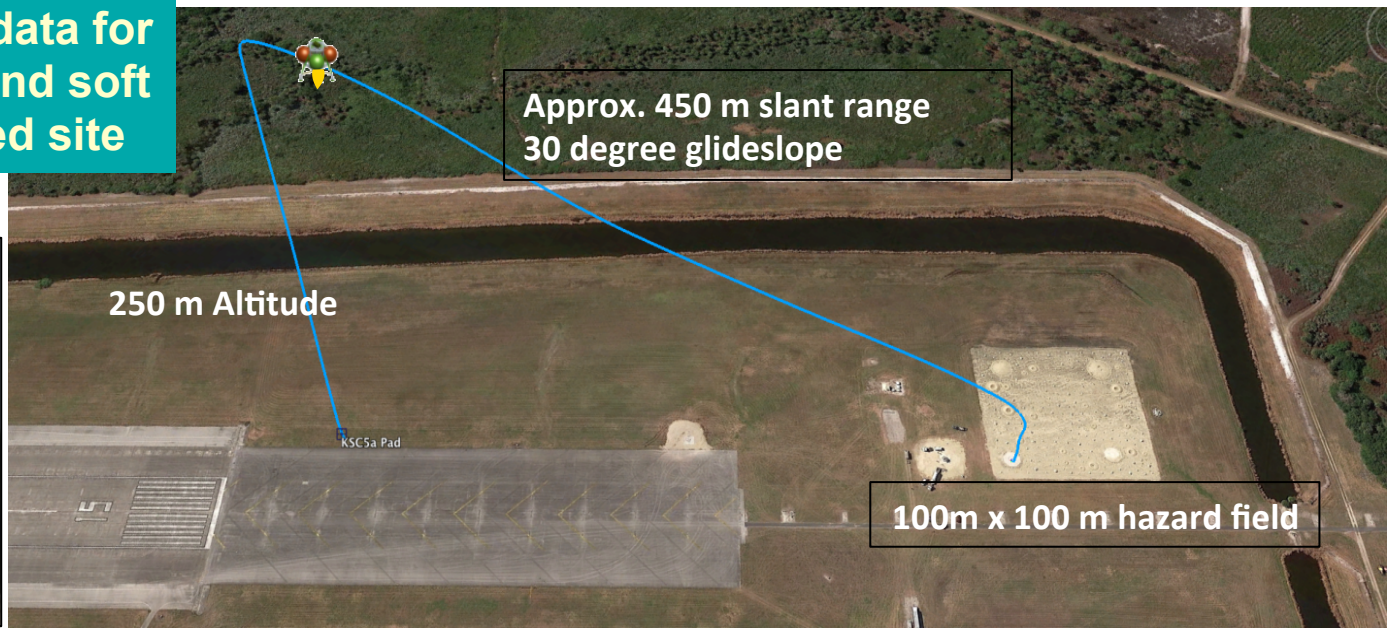
NDL
Optical Head

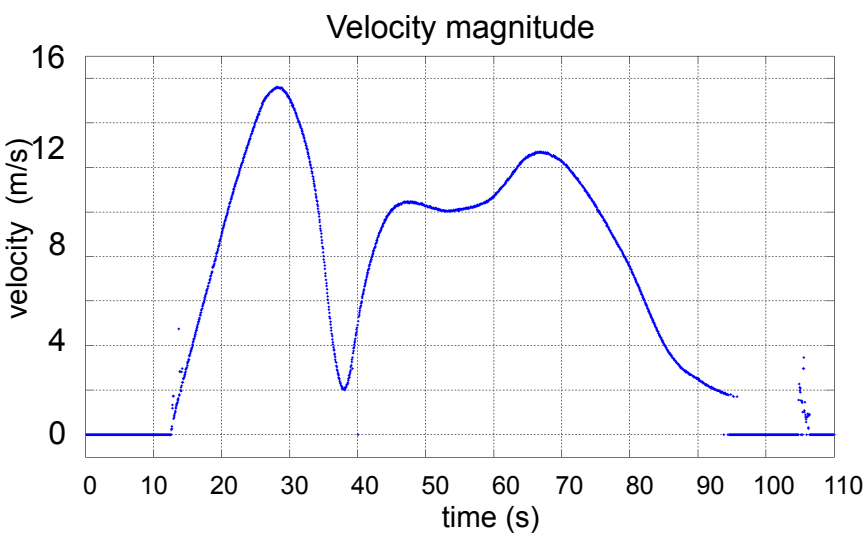


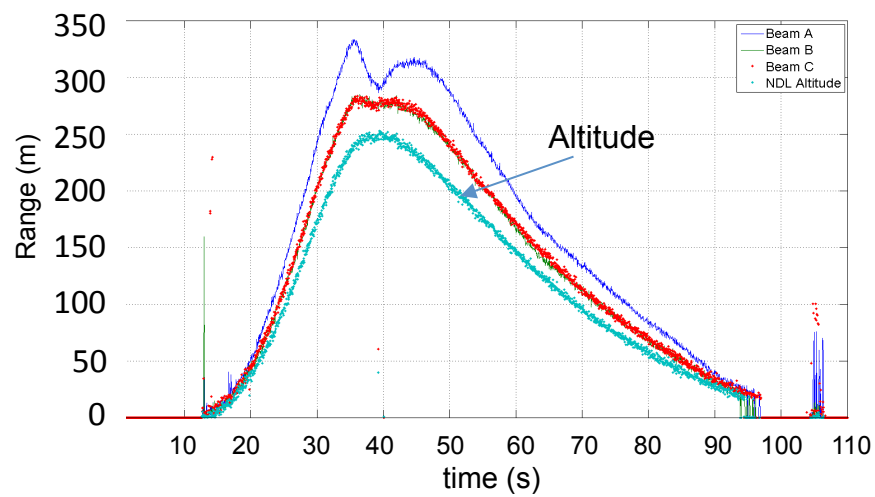
Morpheus Flights: Closed-Loop Demonstration

NASA-KSC, 2014

NDL provided critical data for precision navigation and soft landing at the selected site







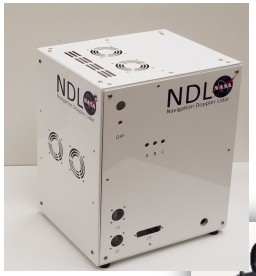
Gen 3 NDL Development (FY2015 – FY2017)

ALHAT Prototype (Gen 2)

AES
Lander Tech

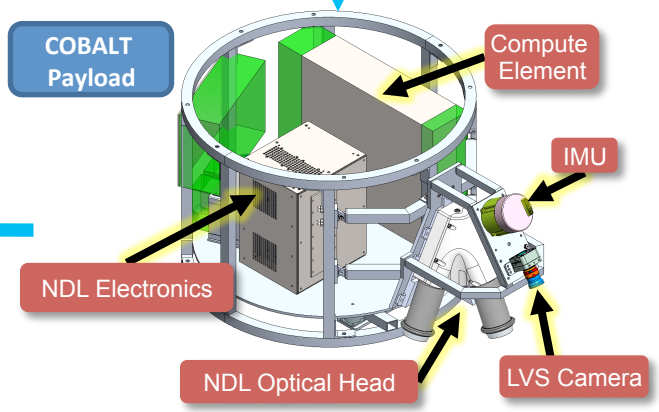
- Max Velocity from 75 m/sec to 200 m/sec
- Max Range from 3 km to 4 km
- Reduced size and mass by 40%

Gen 3 NDL



AES
Lander Tech

- Integrate with LVS (COBALT instrument)
- Conduct ground and helicopter Test integrated



COBALT (CoOperative Blending of Autonomous Landing Technologies)

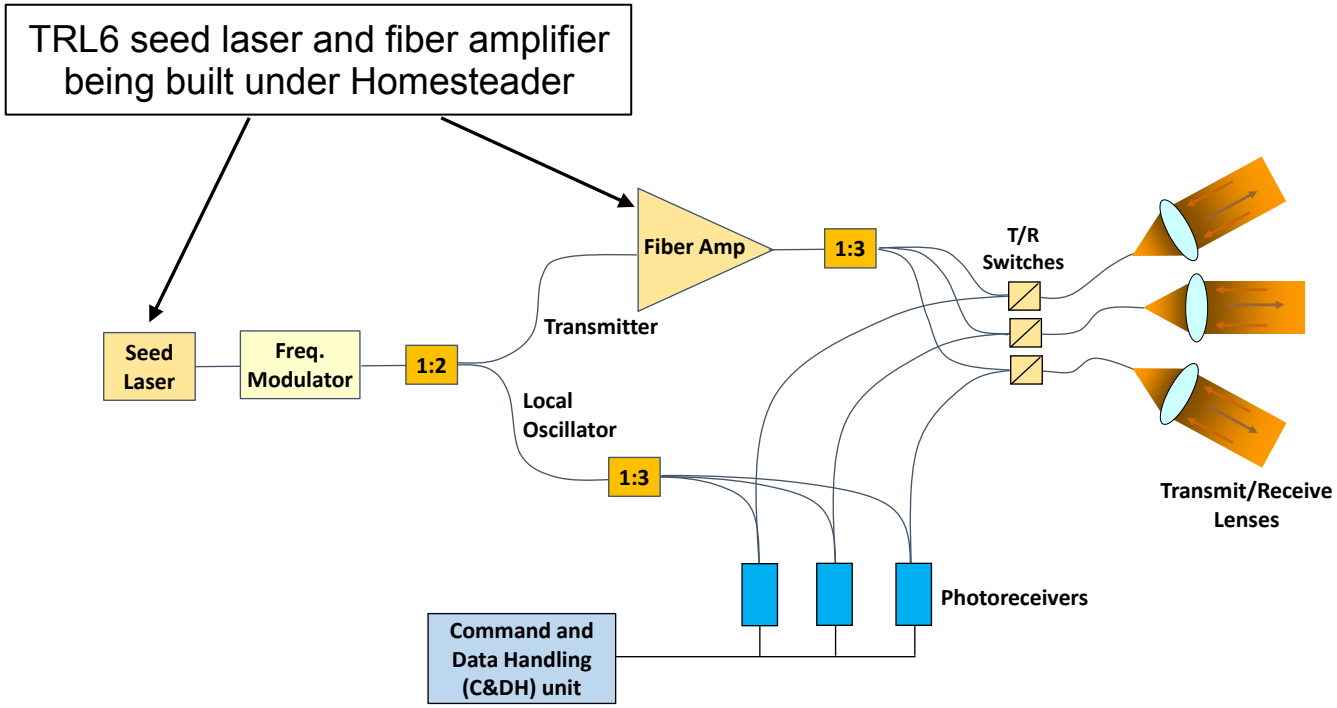
FOP

- Integrate COBALT into Masten vehicle
- Conduct open and closed-loop flights

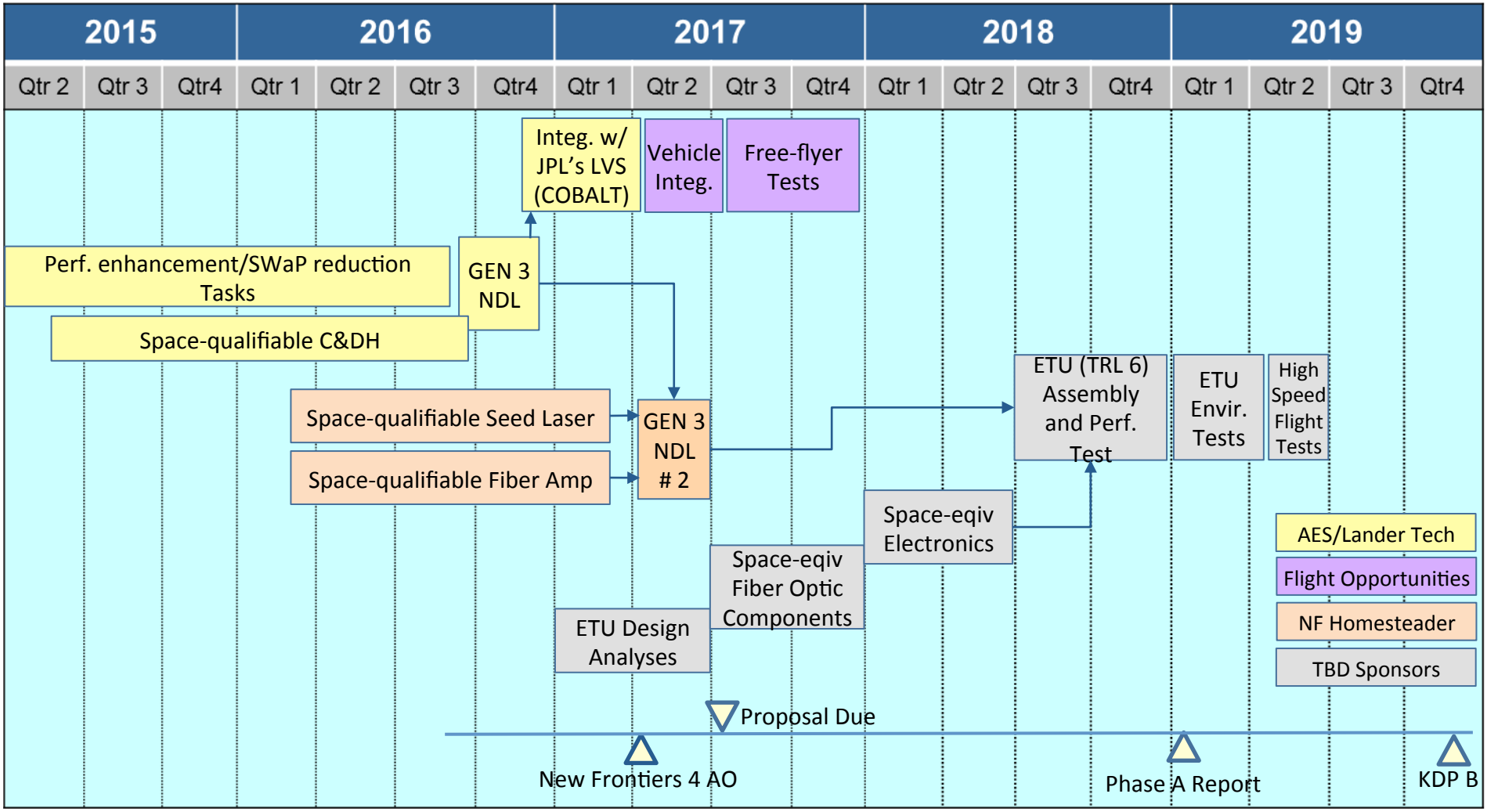
Xodiac

New Frontiers Homesteader Project

- Reduce risk for the development of a spaceflight NDL sensor
- Build and test TRL 6 seed laser and fiber amplifier
- Integrate with NDL and conduct performance tests

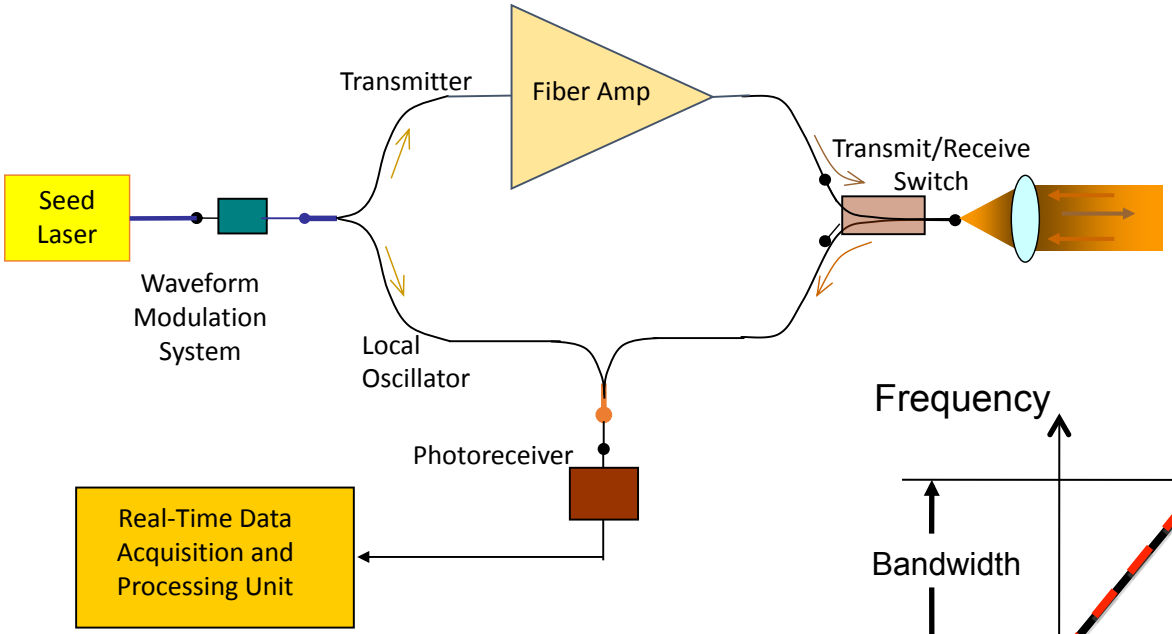


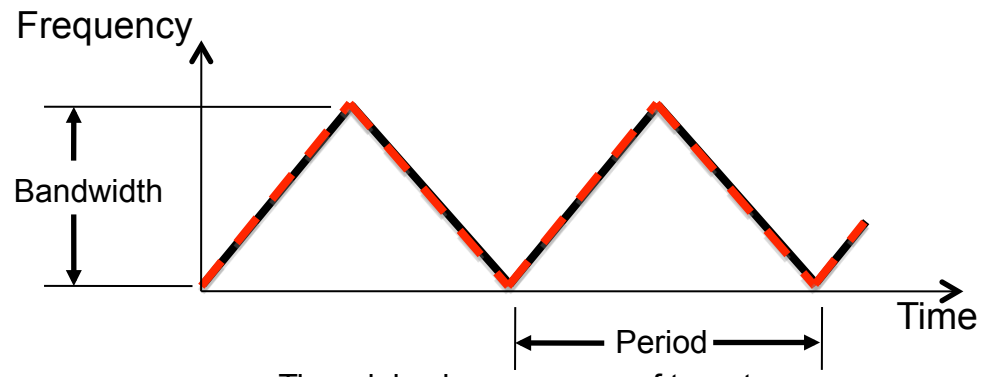
NDL Development & Infusion Plan



Backup

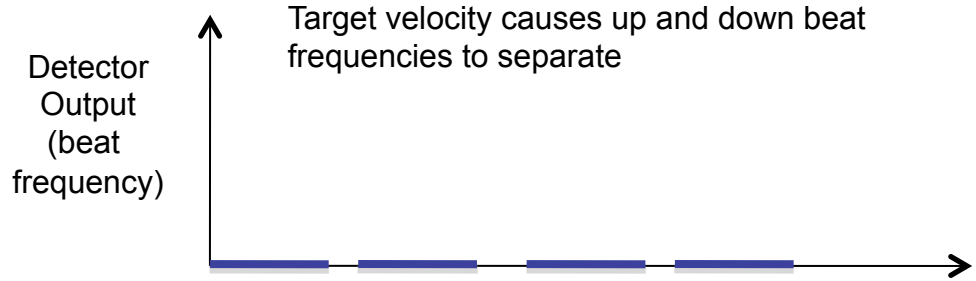
Principle of NDL



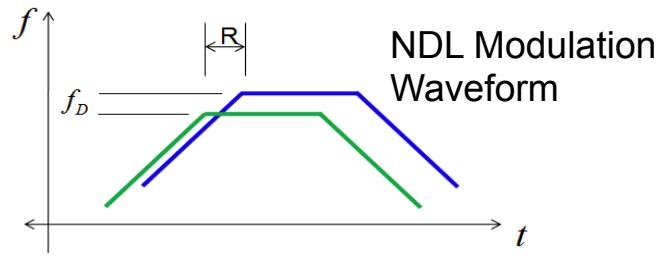


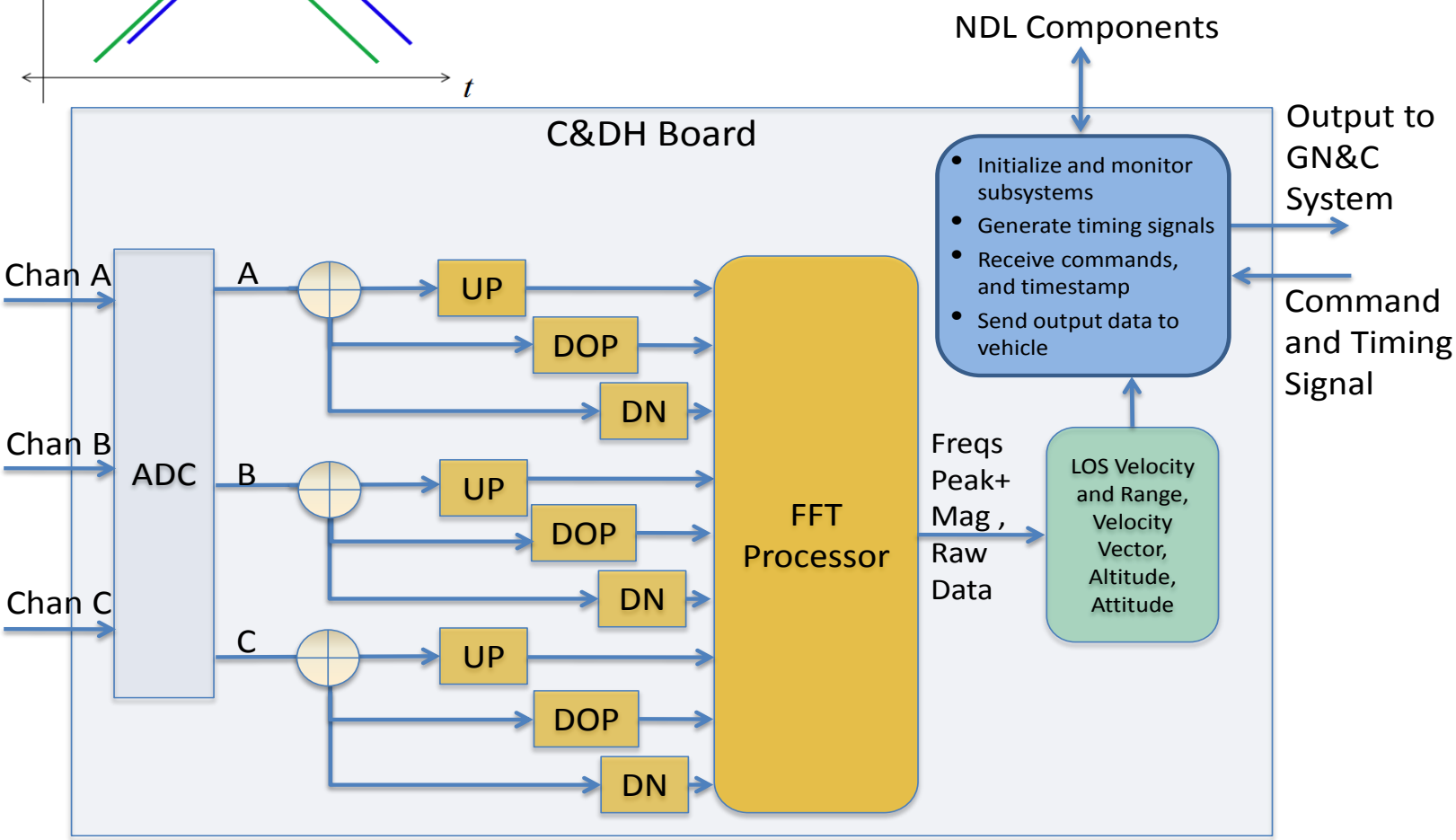
Time delay is a measure of target range

Target velocity causes up and down beat frequencies to separate



NDL Real-Time Processor & System Controller





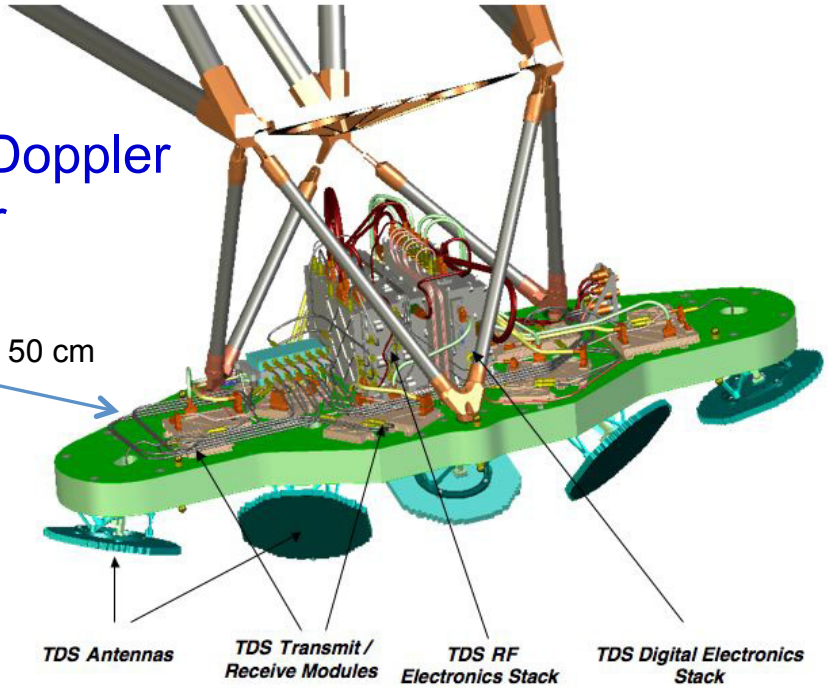
Gen 2 NDL used in Morpheus/ALHAT Tests

- Fully-autonomous operation
- Integrated real-time processors
- Subjected to thermal and vibration tests
- Helicopter and closed-loop Morpheus flight tests as an integrated sensor of the GN&C system

- All the lidar components are housed in the electronic chassis.
- Optical head consists of three transmit/receive lenses connected to the chassis via a long armored fiber optic cable.
- Optical head mounts rigidly to the body of the vehicle with a clear view of the ground while the electronic chassis may be installed anywhere on the vehicle.

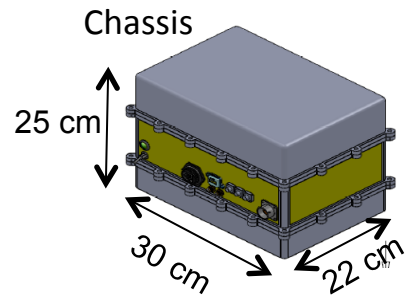
Comparison of NDL and MSL Radar

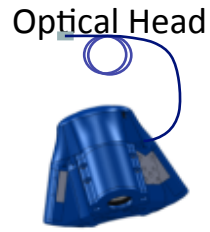
MSL Doppler Radar



6 antennas each 22 cm diameter, 4 cm thick

Navigational Doppler Lidar Flight Unit





18 cm dia x 20 cm H

	MSL Radar	Gen 3 NDL	Flight NDL
Mass (kg)	26	15	13
Power (W)	120	90	75

- 35X higher velocity and altitude precision
- An order of magnitude higher data update rate
- 3 orders of magnitude tighter beams eliminating false alarms due to target clutter and terrain features
- 40% reduction in power, 50% in mass, and 60% in size

NDL Specifications

Parameter		Gen 2	Gen 3
LOS Velocity Error[a]		0.2 cm/sec	0.2 cm/sec
LOS Range Error[a]		30 cm	30 cm
Maximum LOS Range		2500 m	4000 m
Data Rate		20 Hz	20 Hz
Dimensions	Electronic Chassis	44 x 38 x 16 cm	29 x 23 x 20 cm
	Optical Head	34 x 33 x 21 cm	34 x 33 x 21 cm
Mass	Electronic Chassis	16.4 kg[b]	10 kg[c]
	Optical Head	5.2 kg	5 kg
Power (28 VDC)		95 W[b]	90 W[c]

a. Errors do not include platform contributions (vibration and angular motions)

b. Heatsink and fans module adds 4.9 kg and 55 W to ALHAT unit

c. Heatsink and fans module adds 1.5 kg and 10 W to GEN 3 unit

Optical Head

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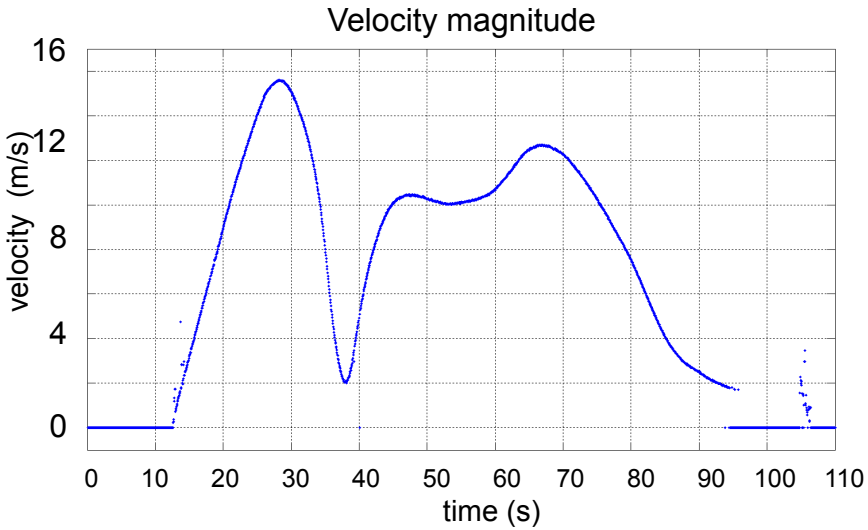

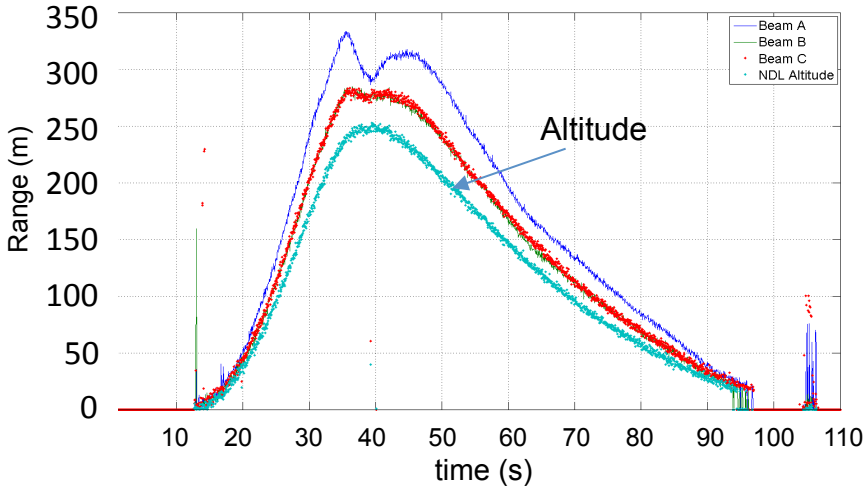

Morpheus/ALHAT Flight

https://www.youtube.com/watch?v=M3D9m5zhhF8

TRL 6 Qualification Tests

TEST	CONDITION	UNITS
High Temperature Storage	85 C, 2000 hrs	3
Low Temperature Storage	-40 C, 72 h	3
Thermal Cycling	-40 C to +85 C, 100 cycles	3
Actively Monitored Thermal Cycling (not a Telcordia test)	0 to 50 C, monitor power and wavelength @ 10 deg intervals, 3 cycles	3
Thermal Shock	0 C to 100 C, 20 cycles	3
Mechanical Shock	500 G, 1 ms, 5 cycles/axis	3
Vibration	20 G, 20 to 2000 Hz	3

- Compliance with vacuum and radiation requirements will be verified analytically
  - Gamma Radiation: 100 krad total dose at 25 C
  - Vacuum: 1.5 x 10^{-5} Torr ambient pressure