# Technology Plan for the Direct Detection Subsystem of a Space-Based Hybrid Doppler Wind Lidar

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# Direct Detection Wind Lidar Key Technologies

DRAFT

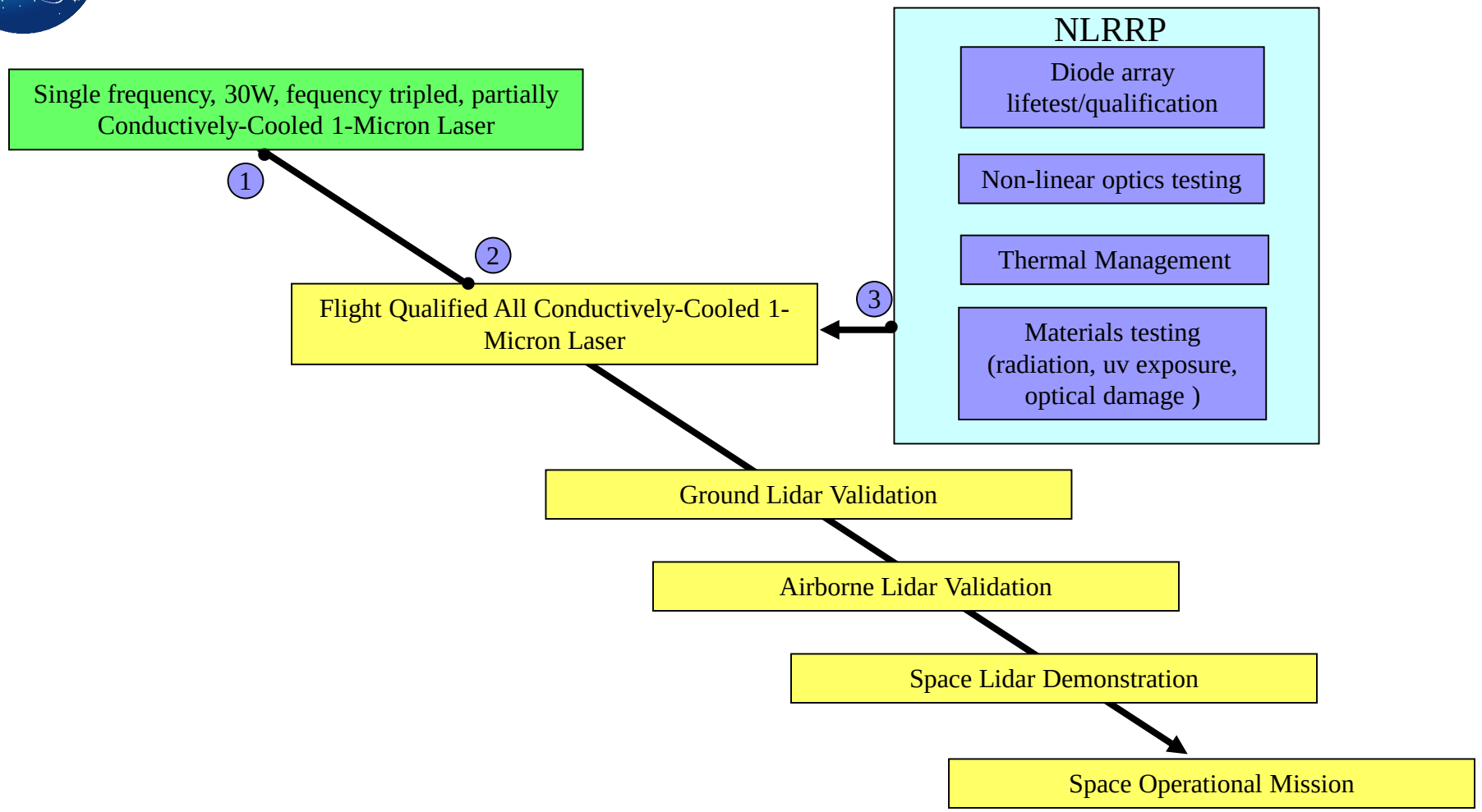
- High spectral resolution all solid state laser transmitter
  - Well developed diode-pumped Nd:YAG technology for efficient, long-life, space qualified laser
- High spectral resolution optical filters
  - High resolution, high throughput, stable, tunable optical filters for Doppler wind measurement
- Photon counting detectors at 355 nm and 1064 nm
  - Space qualified high quantum efficiency detectors and arrays capable of photon counting
- Novel large aperture telescopes and scanning optics
  - Low mass/aperture ratio (e.g. composite optics, deployables); Simplified scanning (e.g. Holographic or Diffractive Optical Elements)

# Single frequency diode-pumped Nd:YAG laser

DRAFT

- **Function**: Pulsed, injection seeded transmitter for direct detection Doppler lidar tropospheric wind profiling.
- **Performance Objectives**
  - Pulse energy at 1064 nm 1-3J with 10-100 Hz prf
  - All solid state. Lifetime > $5X10^9$ shots.
  - Single frequency, 20 ns pulselength, <200 MHz spectral bandwidth @ 355 nm
  - Efficient harmonic conversion (>35%) to 355 nm
  - Low mass, low power, 6-8 % wallplug efficiency.
  - Conductive cooling.
- **Approach** : Utilize well developed injection seeded diode pumped Nd:YAG laser technology. Focus technology development on efficiency, conductive cooling, lifetime.
- **Status**
  - GLAS laser delivers ~4% wallplug in space qualified package.
  - Efficient 100 W all solid state rugged design demonstrated (TRW)
- **Validation:** Demonstrate in ground and airborne testbed.

# Direct Detection Doppler Lidar Pulsed Laser



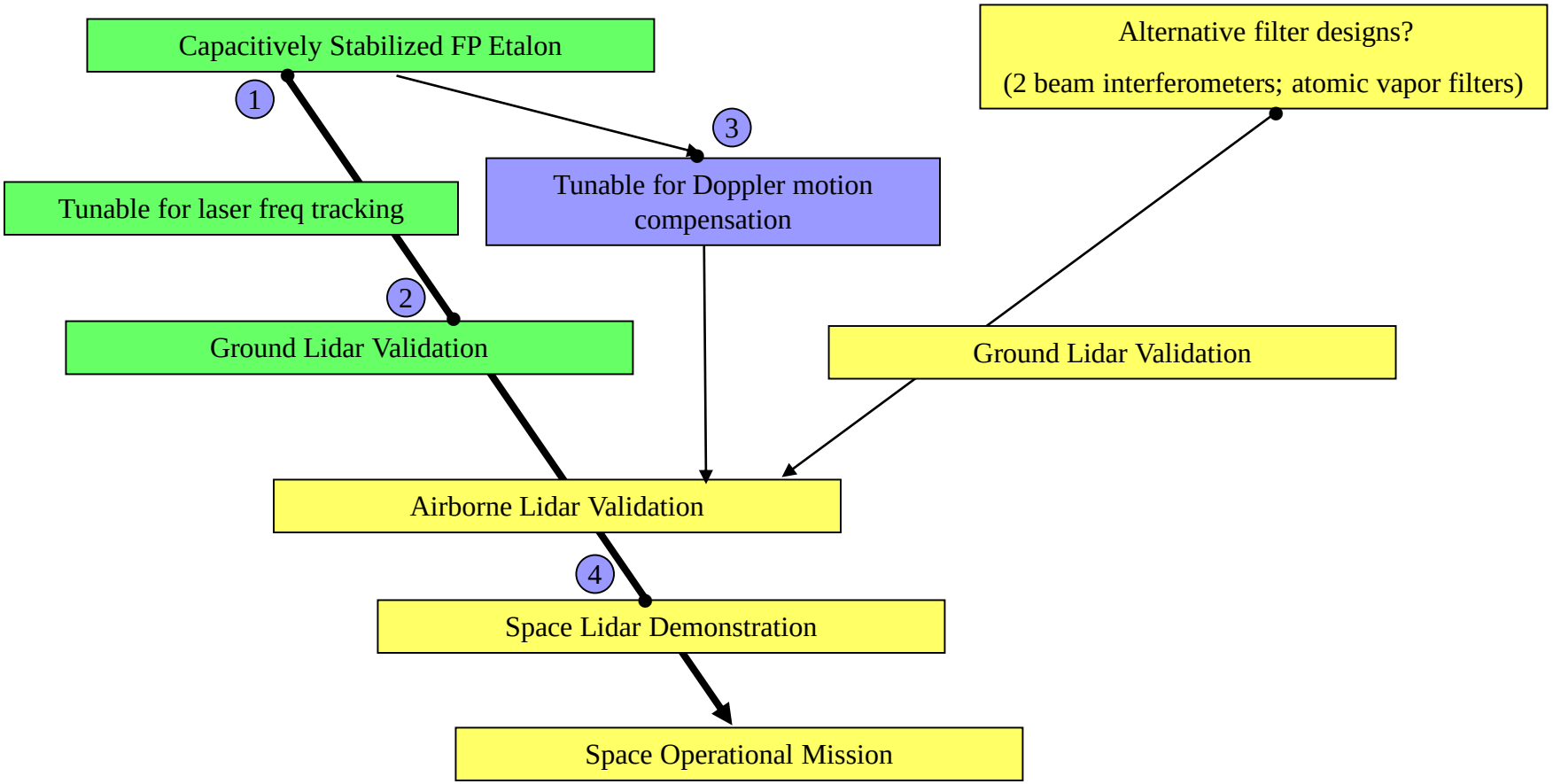
# High spectral resolution optical filters

- **Function**: Narrowband optical filter for tropospheric wind profiling using the direct detection Doppler lidar.
- **Performance Objectives**
  - 100 -1500 MHz spectral bandwidth.
  - Operation at 355 nm and 1064 nm.
  - Peak transmission > 70 %.
  - Tunable to provide compensation for spacecraft motion*
    - 1 ms response time
    - Frequency repeatability - $6x10^{-10}$ (0.1 m/s)
  - Low mass, low power.
  - Active alignment stabilization for long term unattended operation.

- **Baseline Approach**: Capacitance stabilized piezoelectrically tunable Fabry-Perot etalon with prefiltering. Assess other technologies.
- **Status**
  - Breadboard double edge and fringe imaging filters demonstrated in ground based lidar wind measurements.
  - Capacitance stabilization used in space on UARS
  - Scalable engineering model demonstrated in CALIPSO program (MAC)
- **Validation**: Demonstrate in ground and airborne testbed

* Optional

# DDDL Lidar High Spectral Resolution Optical Filter



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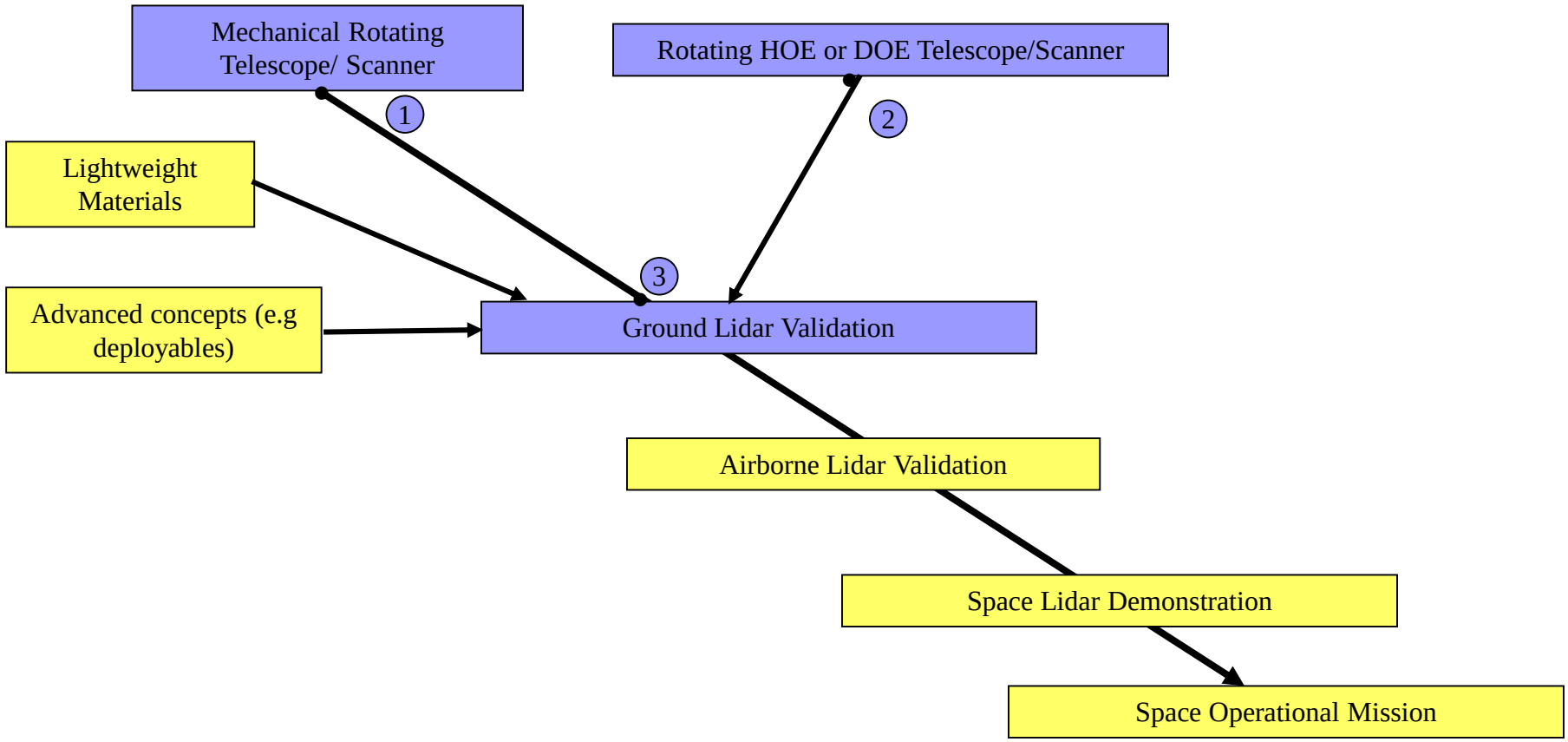
# Direct Detection Doppler Lidar Telescope/Scanner




Primary Path
Secondary Path

Completed Item

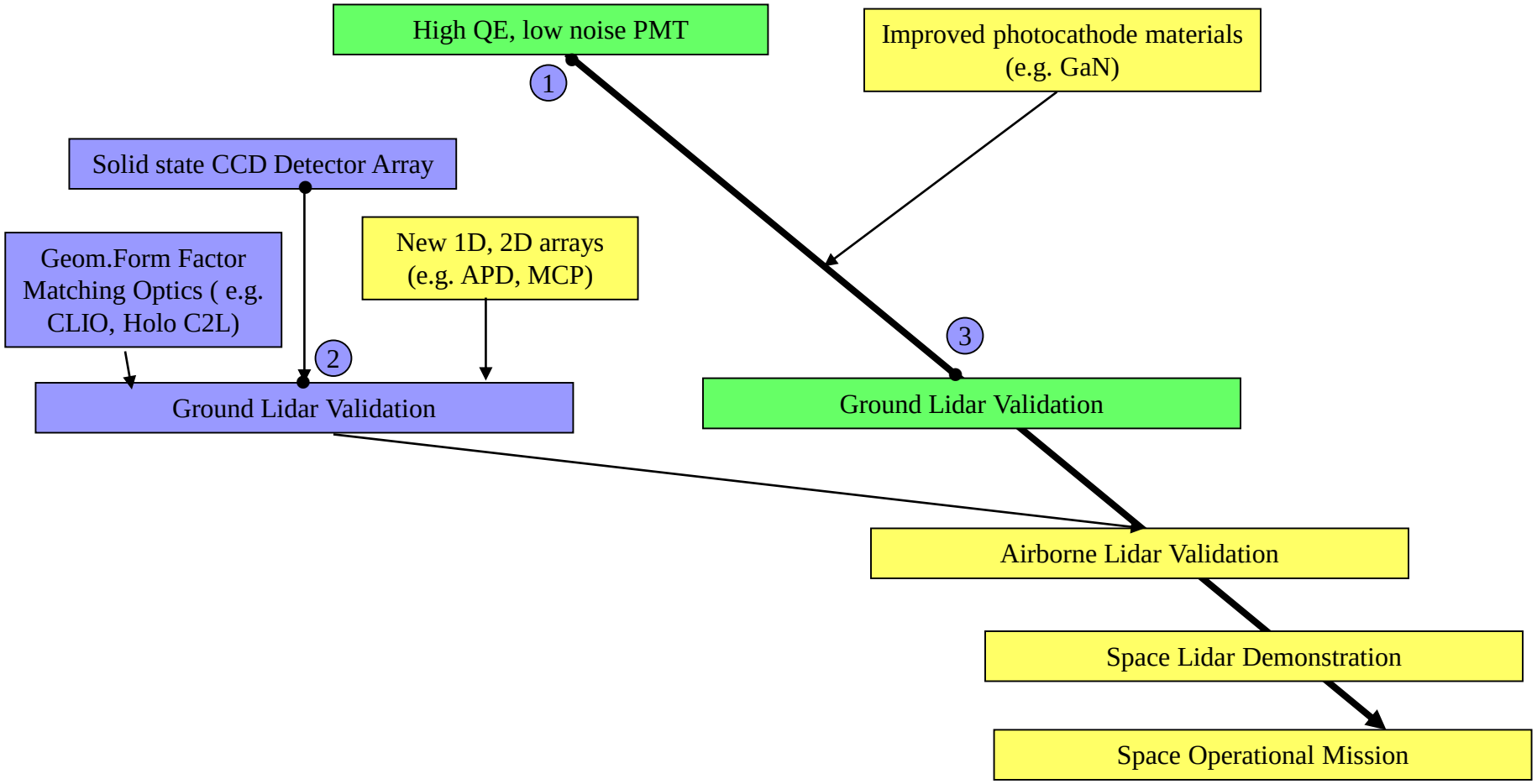
In Progress

1 Milestone

# Photon counting detectors

- **Function**: High efficiency, low noise detectors and arrays capable of photon counting in direct detection wind lidar receivers at 355 nm and 1064 nm.
- **Performance Objectives**
  - High quantum efficiency
  - Low internal noise (dark current, read noise)
  - High internal gain
  - Large dynamic range >100 MHz count rate to accommodate clouds, ground return
  - No cryogenic cooling.
  - Compatible with long term operation in space environment
- **Baseline Approach** : Improve photocathode materials at 355 nm. Develop new “solid-state PMT” photon counting detectors and arrays (e.g. CCD, microchannel plate, APD arrays)
- **Status**
  - > 30% QE photocathode space qualified single element PMTs available at 355 nm (Hammamatsu). 70% QE CCDs demonstrated in ground based lidar (GroundWinds)
  - Enhanced QE Si APD photon counting module (Perkin Elmer) developed for GLAS
- **Validation:** Demonstrate in ground and airborne testbed.

# Direct Detection Doppler Detectors and Arrays



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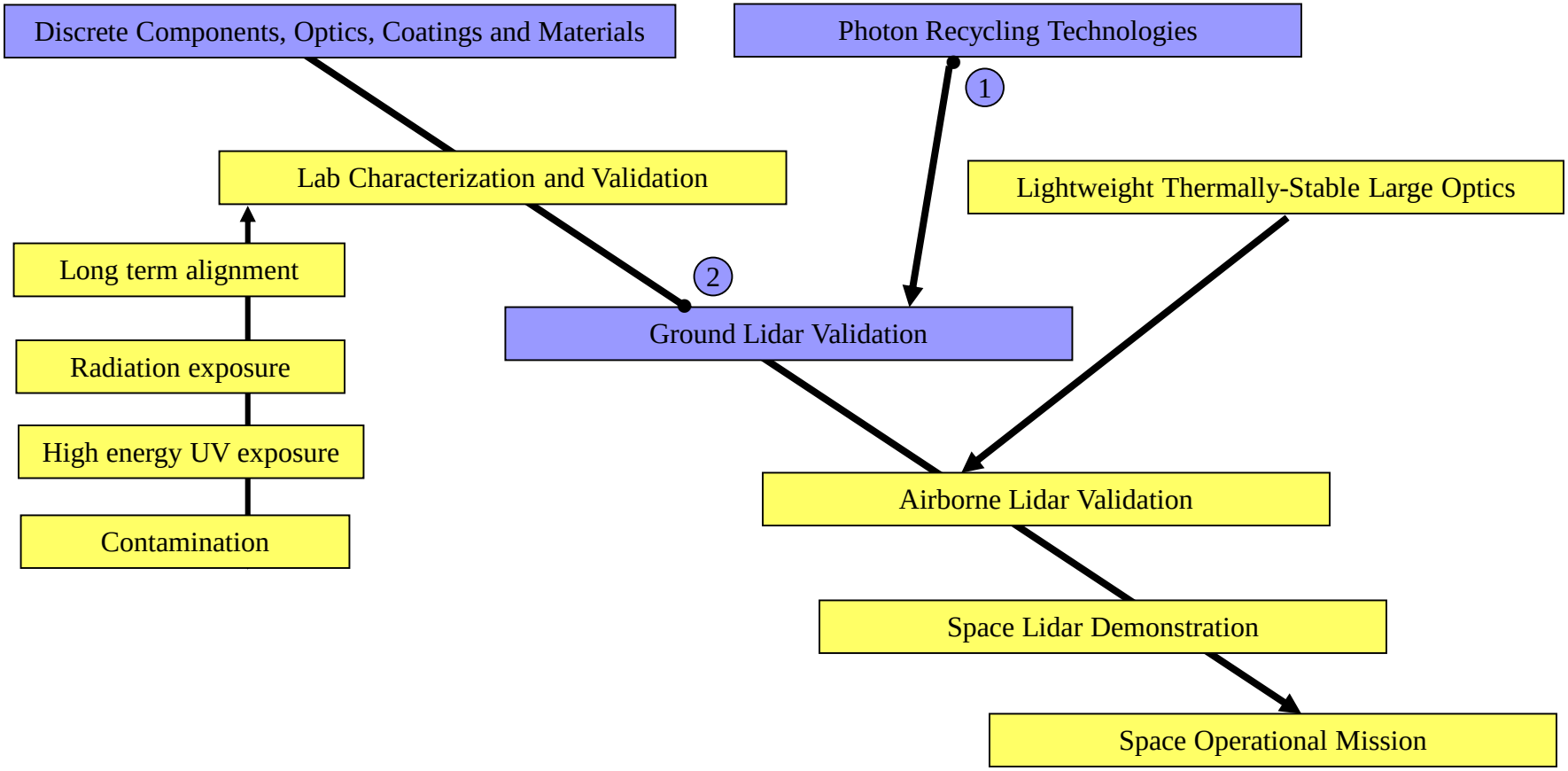
# Direct Detection Doppler Lidar Photon Efficiency




Primary Path
Secondary Path

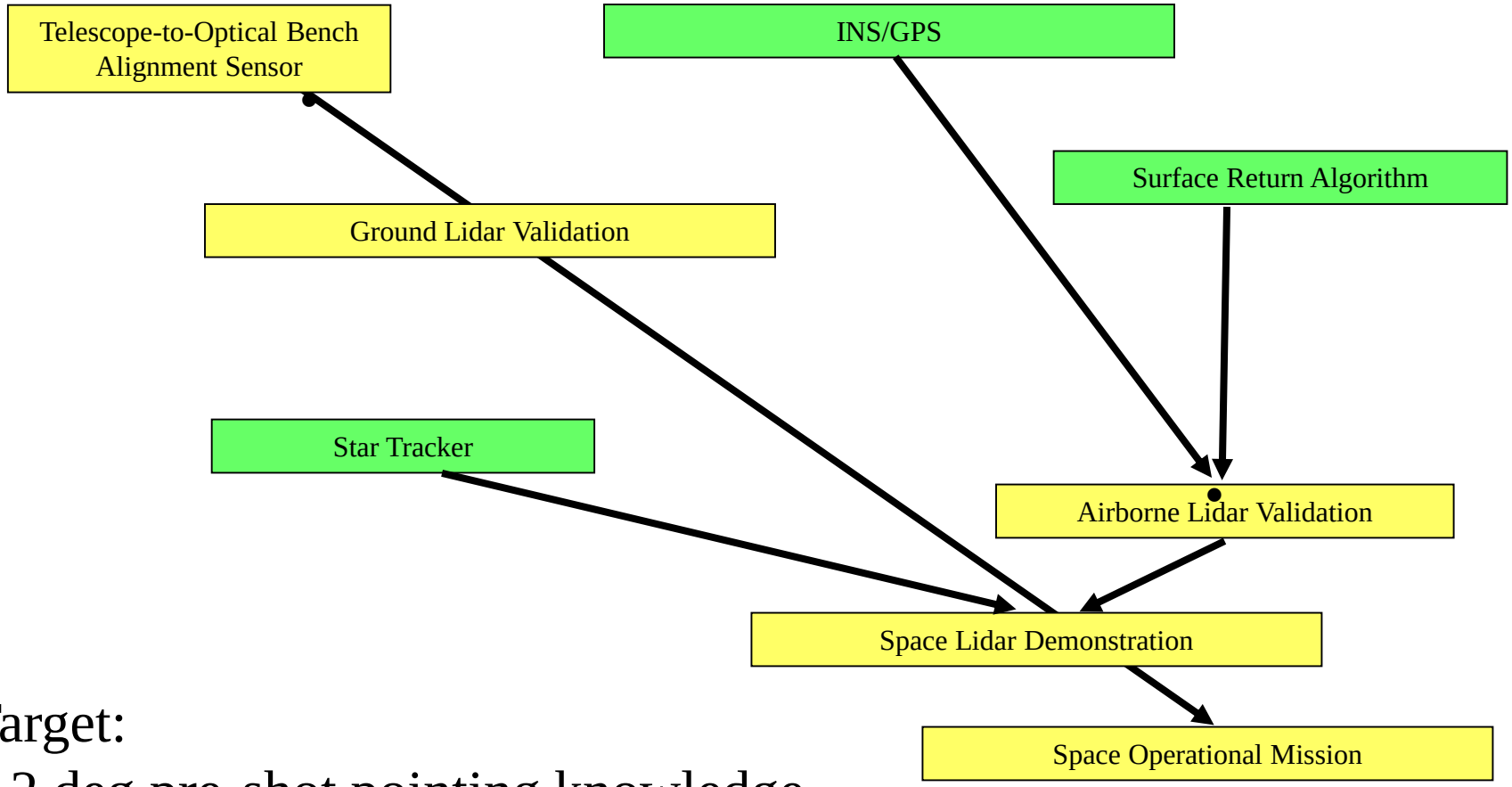
Completed Item

In Progress

1 Milestone

# Doppler Lidar Pointing Technology

(Requirements shared with coherent *except for round trip boresight*)




Target:
0.2 deg pre-shot pointing knowledge
50 μrad final pointing knowledge

Primary Path
Secondary Path

Completed Item

In Progress

1 Milestone

# Progress Mark Explanations

**Pulsed Laser**

1. TRW CAPPSL and Zephyr design study; SBIR Phase II studies (Fibertek, CEO, Litecycles, QPeak)
2. GLAS, CALIPSO flight laser programs
3. NASA Laser Risk Reduction Program

**Telescope/Scanner**

1. Multiple concepts examined by GSFC ISAL/IMDC. HOE concept selected for mass reduction
2. HOE scanner developed in multiple SBIR Phase II studies @355/532/1064 nm
3. NASA GSFC ground and airborne backscatter lidar demonstration at 1064 nm (HARLIE)

**High Resolution Filters**

1. Michigan Aerospace/GroundWindsHI; Zephyr Engineering Model
2. GroundWinds HI; NASA GLOW
3. Zephyr Engineering Model demonstrated 3 ms tuning
4. DE; HRDI; MAC CALIPSO prefilter

**High QE, low noise detectors and arrays**

1. Commercially available e.g. Hammamatsu
2. GroundWinds NH,HI
3. NASA GLOW

**Photon Efficiency**

1. MAC/GroundWinds demonstrated fiber recycler concept
2. Discrete component system efficiency measured – NASA/GLOW; GrioundWinds

# BACKUPS START HERE

# Tropospheric Wind Sounder - Direct Detection Recommended Technology Investments

- **Solid State Laser Technology**
  - single mode 1µm laser oscillator with harmonic conversion to 0.35 µm
  - laser pump diode reliability
  - thermal management/conductive cooling
  - optics coatings, damage tests
  - non-linear materials testing
  - optical configuration trade studies
  - prototype laser pkg/test

- **Receiver Technology**
  - lightweight deployable telescopes
  - large aperture scanning optics
  - photon counting detectors and arrays
  - high spectral resolution optical filters
  - Novel receiver optical configurations

- **Space systems**
  - On-orbit pointing and alignment

- **Ground Validation**
  - Ground and Airborne Field Test Bed

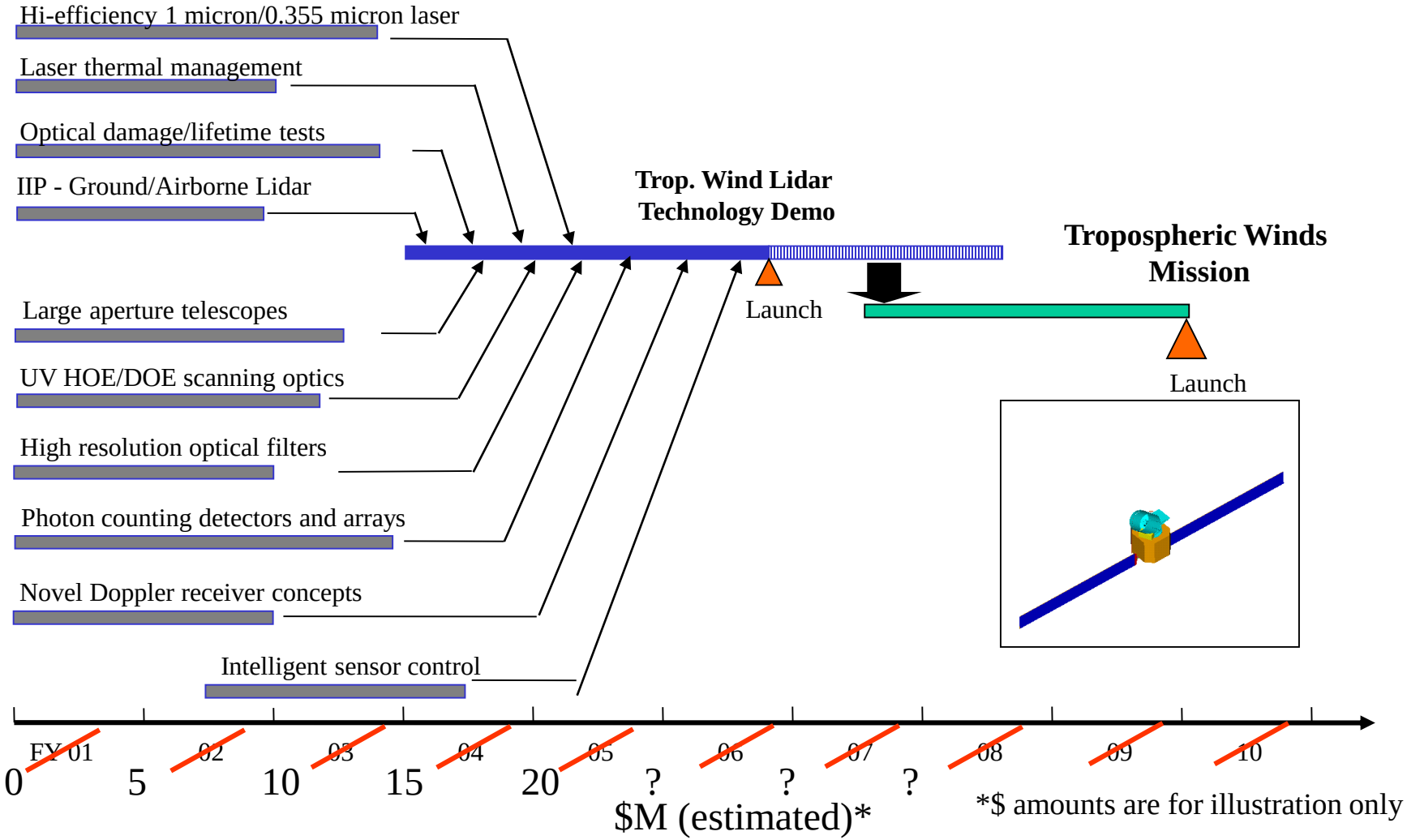
- **Space Technology Demonstration**

# Global Tropospheric Winds - Direct detection

**OBJECTIVE:** **Provides the capability to measure tropospheric vector-wind for altitudes from 0 - 20 km with accuracy of order ~ 1 - 5 m/s within a 0.5 - 1 km atmospheric layer and revisit time of 24-hours.**

**TECHNOLOGY CHALLENGE:**

- **Lidar technology**
- **Instrument pointing**
- **Doppler receiver**

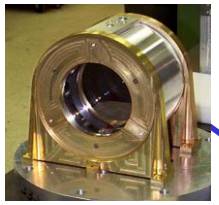



*$ amounts are for illustration only

# Linking Technology and Science

## Component Technologies

Tunable etalon filters



Photon counting detectors

Novel receiver optics

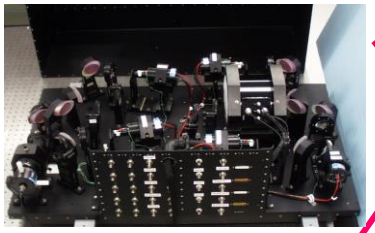
Holographic scanners

1. Evaluate components
2. Establish performance criteria/ specs

## Subsystems

Single frequency lasers

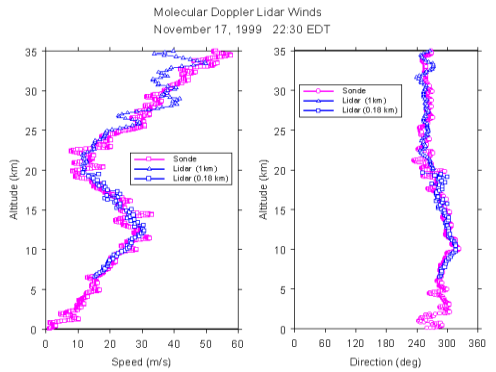
Doppler lidar receivers



Fiber coupled telescopes

1. Evaluate subsystem designs/ concepts
2. Interface issues/answers
3. Environmental sensitivities

## Field measurements




1. Measurement heritage/experience
2. Algorithm development
3. Evaluate atmospheric effects
4. Link technology performance to science product - winds
5. Develop robust instrument models