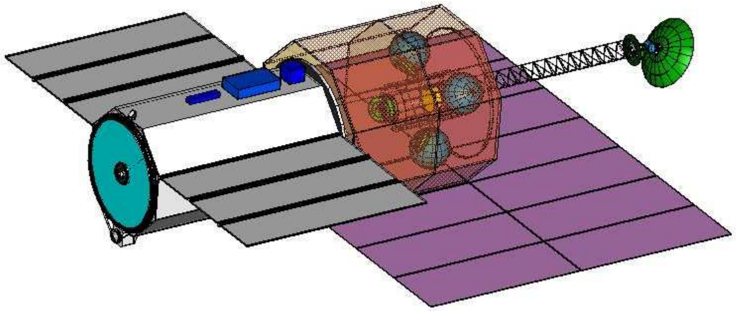
Doppler Wind Lidar Technology Roadmap



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Coauthors –see Reference 2

January 27, 2004

Agenda

- Purpose and Background
- Measurement Concept
- Reference Designs
- Hybrid DWL Point Design
- Activities Leading to Operations
- Near Term Issues
- Requirements Trades
- Component Technology Roadmaps
- Conclusions
- Technology Readiness Time Scale
- References

Purpose

- Achieve mature DWL technology and reduce risk for operational wind profiles from space
- Alternative instrument approaches
- Roadmaps for key technology elements assuming a hybrid instrument
- Sources
  - Government planning document, *GTWS Strategy for Obtaining Operational Wind Profiles from Space* (June 2003)
  - Paper on Working Group Web Site: *Technology Roadmap for Deploying Operational Wind Lidar* (January 2004)

References

1. *Global Tropospheric Wind Sounder (GTWS), A Strategy for Obtaining Operational Wind Profiles from Space*, F. Amzajerdian, R. Atlas, W. Baker, J. Barnes, D. Emmitt, B. Gentry, I. Guch, M. Hardesty, M. Kavaya, S. Mango, K. Miller, S. Neeck, J. Pereira, F. Peri, U. Singh, G. Spiers, J. Yoe (June 20, 2003)
2. *Technology Roadmap for Deploying Operational Wind Lidar*, F. Amzajerdian, D. Emmitt, B. Gentry, I. Guch, M. Kavaya, K. Miller, J. Yoe, (January 20, 2004)

Background

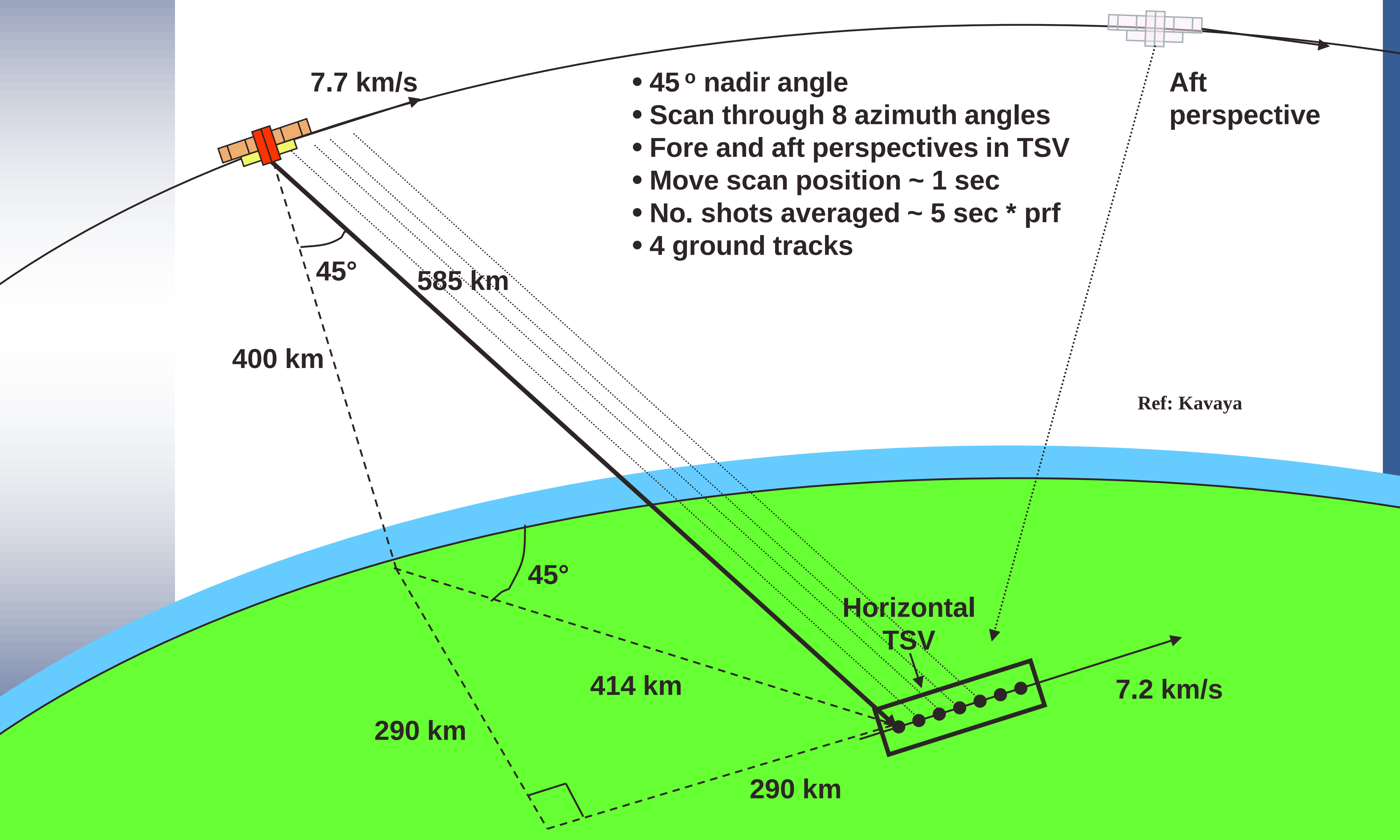
- Stable data requirements
  - Validated by OSSEs
  - Quantified benefits
- Alternative DWL techniques
  - Coherent (reference designs)
  - Direct Detection (reference designs)
  - Hybrid (point design)
- Need to advance technology readiness
  - Lasers
  - Detectors
  - Low-mass telescopes
  - Scanners
  - Momentum compensation

Background (concluded)

- Current instrument activities
  - Demonstrating ground and airborne DWLs
  - IPO
    - Airborne work on calibration/validation
    - Hybrid concepts
  - NOAA/UNH
    - Operating 2 GroundWinds lidars
    - Developing a balloon demonstration
  - NASA Laser Risk Reduction Program (LRRP)
- Related activities
  - Japanese National Space Development Agency (NASDA)
  - European Space Agency (ESA)

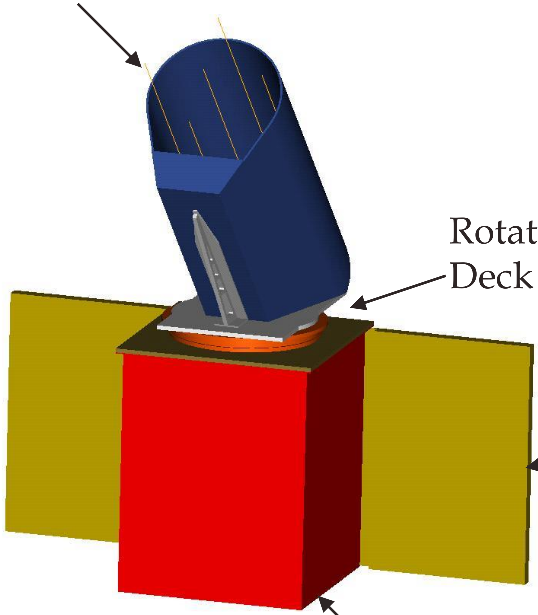
Measurement Concept

- 45 ° nadir angle
- Scan through 8 azimuth angles
- Fore and aft perspectives in TSV
- Move scan position ~ 1 sec
- No. shots averaged ~ 5 sec * prf
- 4 ground tracks

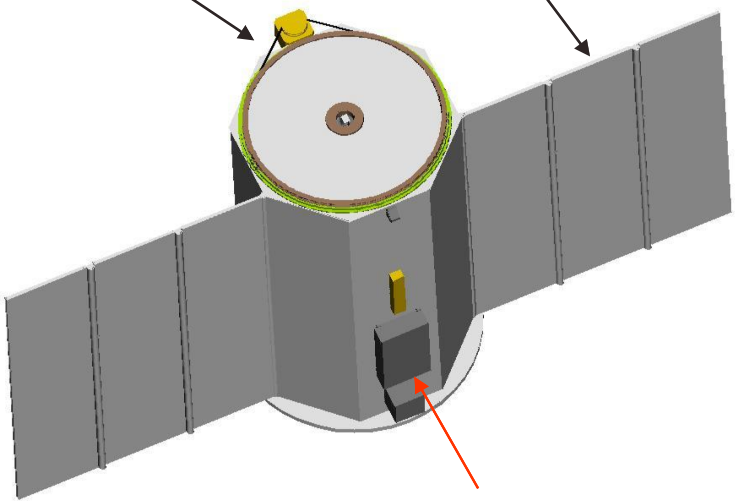


Ref: Kavaya

Reference Designs



Coherent



Direct

Note: Large solar arrays not shown

Reference Designs (concluded)

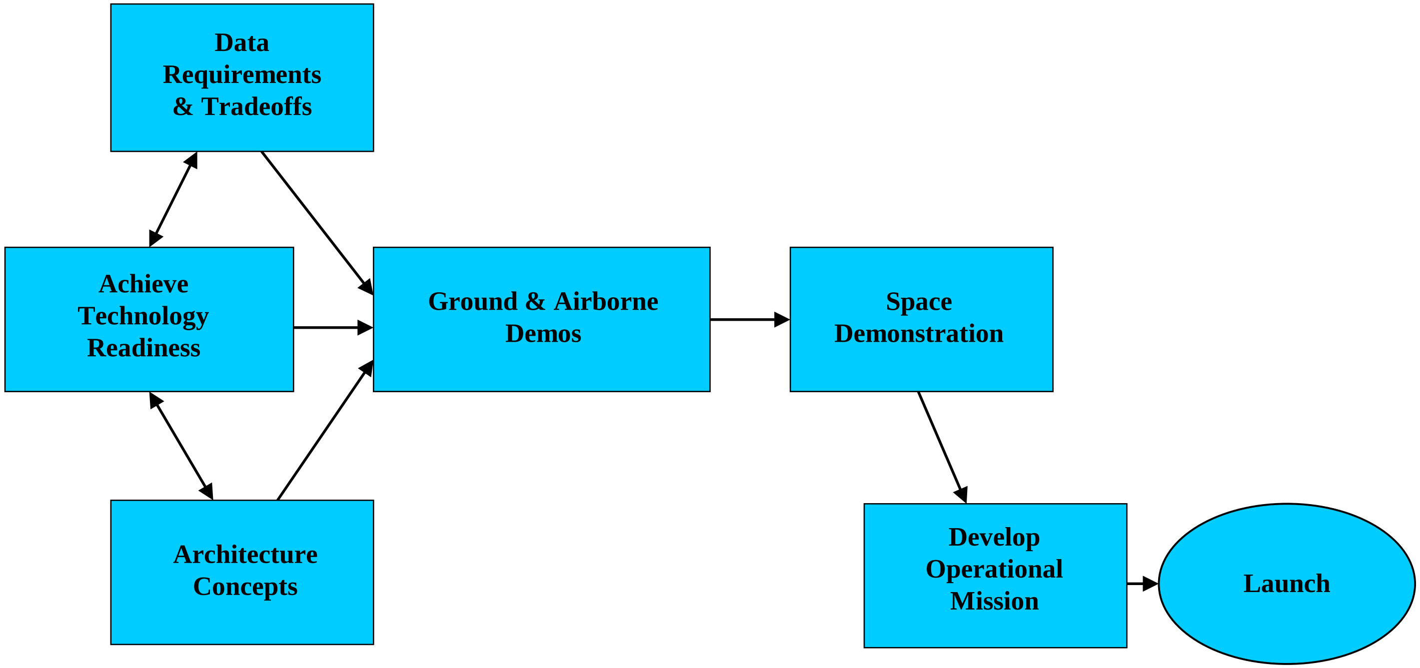
- Roughly comparable cost and complexity
- Large and heavy spacecraft
- Massive optical components
- Extremely high electrical power consumption

Hybrid DWL Point Design

- 2 subsystems, coherent and direct detection
- End-to-end improvement vs. single DWL
  - Coherent subsystem: 15 to 30 X
  - Direct Detection subsystem: 4 to 8 X
- Reduced technology requirements end-to-end
  - Laser power, telescope, optical efficiency, detection
  - Spacecraft mass, energy, momentum compensation
- Should make development more tractable
- But may complicate mission and spacecraft issues

Emmitt (2004)

Activities Leading to Operations



Near Term Issues

- Technology development
- Data requirements vs. benefits trade study
- Architecture concepts
  - Hybrid reference design
  - Calibration and validation
  - Mission and spacecraft alternatives
  - Impacts on data products from atmospheric properties, DWL alternatives, and spacecraft mechanics

Requirements Trades

Threshold Requirement	Technology Risk Impacts	Mechanism
Vertical TSV [1] Resolution (1 km)	Laser, detector, telescope	Increasing vertical TSV dimension increases photon accumulation
Horizontal TSV Dimension (100 km)	Laser, detector, telescope, scanner	Increasing horizontal TSV dimension, combined with relaxing horizontal resolution would allow more shot accumulation and simplify scanner
Horizontal Resolution - Along Track (350 km),	Laser, detector, telescope, scanner	Increasing beyond 350 km increases time for shot averaging and scanner movement
Horizontal Resolution – Cross-Track (4 lines)	Laser, detector, telescope, scanner	Less Cross-Track observation lines increases time for shot accumulation and scanner movement
2 discrete perspectives in TSV	Scanner	Consider non-discrete method, e.g., conical scan
Wind Velocity Accuracy	Laser, telescope, detector	Reduced accuracy reduces laser, optics, and detector requirements

[1] Target Sample Volume (TSV) is the maximum atmospheric volume averaged in a single wind observation

Component Technology Roadmaps

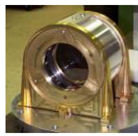
Technology Development	Direct Detection	Coherent Detection	Hybrid Detection
Laser	X	X	X
Optical Filters	X		X
Telescope and Scanner	X	X	X
Detectors, Arrays, Efficiency	X	X	X
Pointing Technology	X	X	X
Tunable LO Laser		X	X
Autoalignment		X	X
Hybrid Ref Designs			X
Hybrid Integration Designs			X

Direct Detection Component and Subsystem Development and Demo

MTS™ Mitretek Systems

Component Technologies

Tunable etalon filters



Photon counting detectors

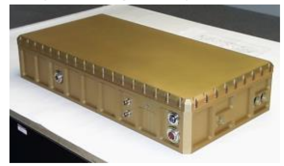
Novel receiver optics

Holographic scanners

1. Evaluate components
2. Establish performance criteria/ specs

Subsystems

Single frequency lasers

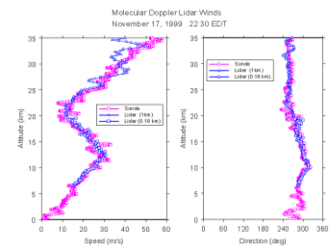


Doppler lidar receivers

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

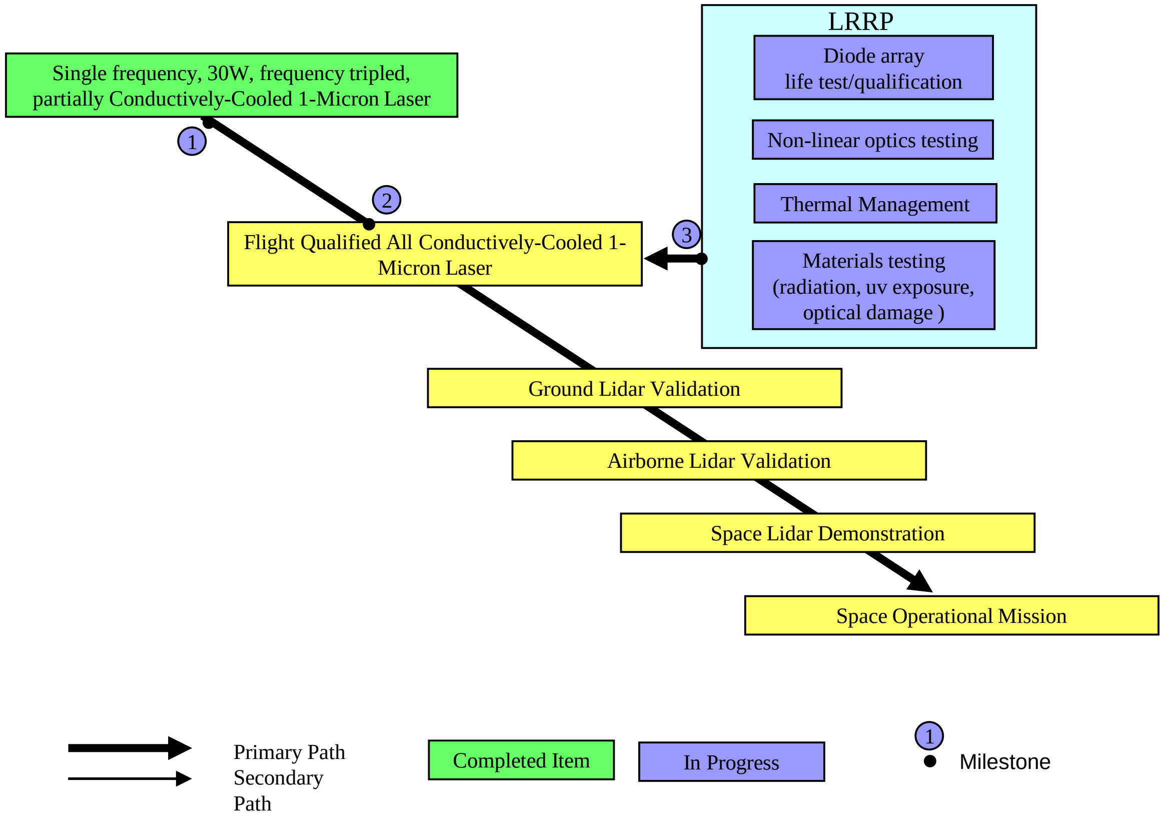
Gentry (2003)

Direct Detection Subsystem Laser Performance Objectives

Material	All solid state
Pulse characteristics	1064 nm 1 to 3 J 20 ns pulse length 10-100 Hz < 200 MHz bandwidth @ 355 nm > 35% harmonic conversion to 355 nm
Lifetime	> 5×10^9 shots
Mass	Low (tbd)
Power	Low (tbd)
Wallplug efficiency	6 to 8%
Cooling	Conductive

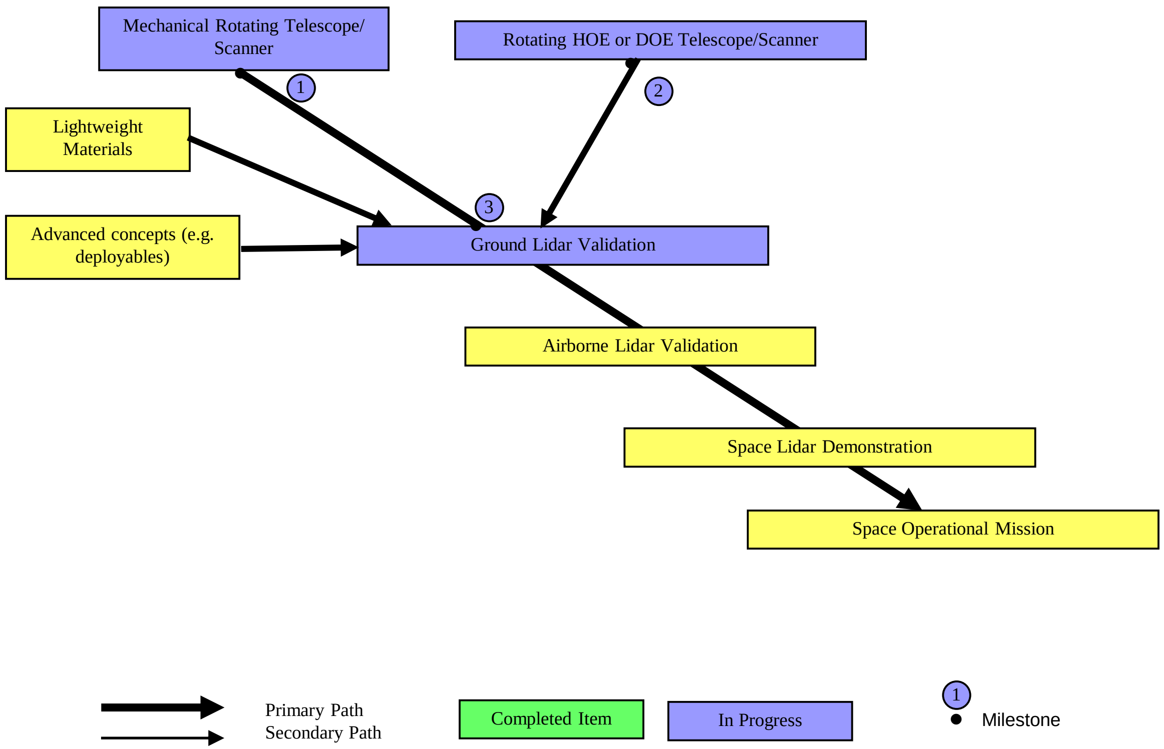
Gentry (2003)

Laser Roadmap – Direct Detection Subsystem



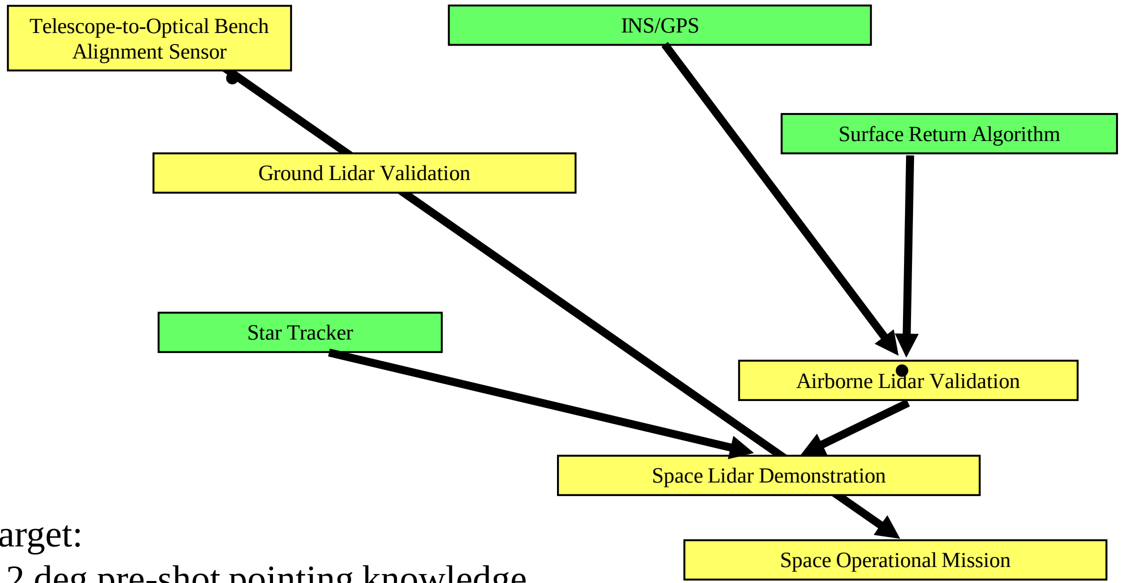
Gentry (2003)

Telescope Roadmap – Direct Detection Subsystem

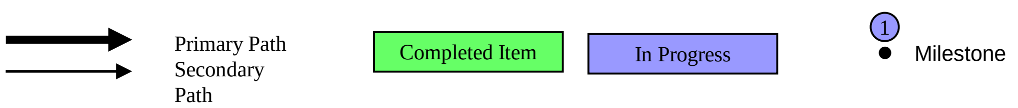


Gentry (2003)

Pointing Technology Roadmap – Direct Detection Subsystem

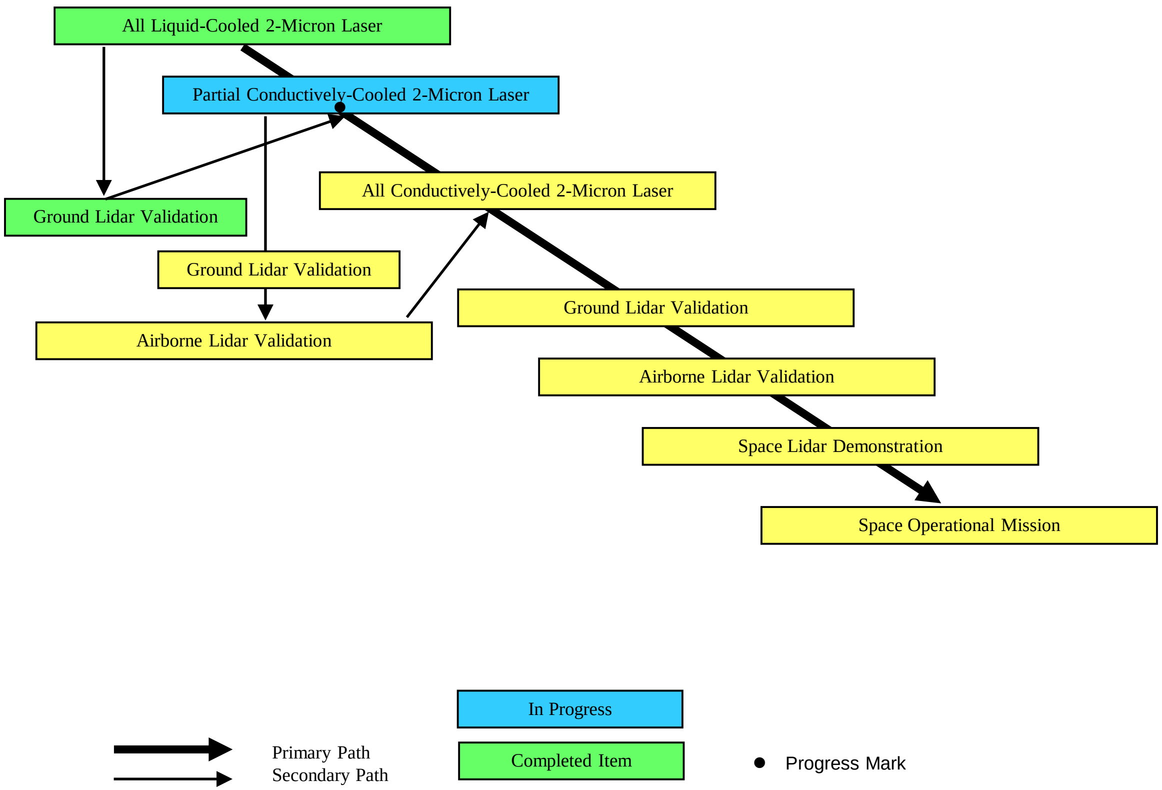


Target:
0.2 deg pre-shot pointing knowledge
50 μrad final pointing knowledge



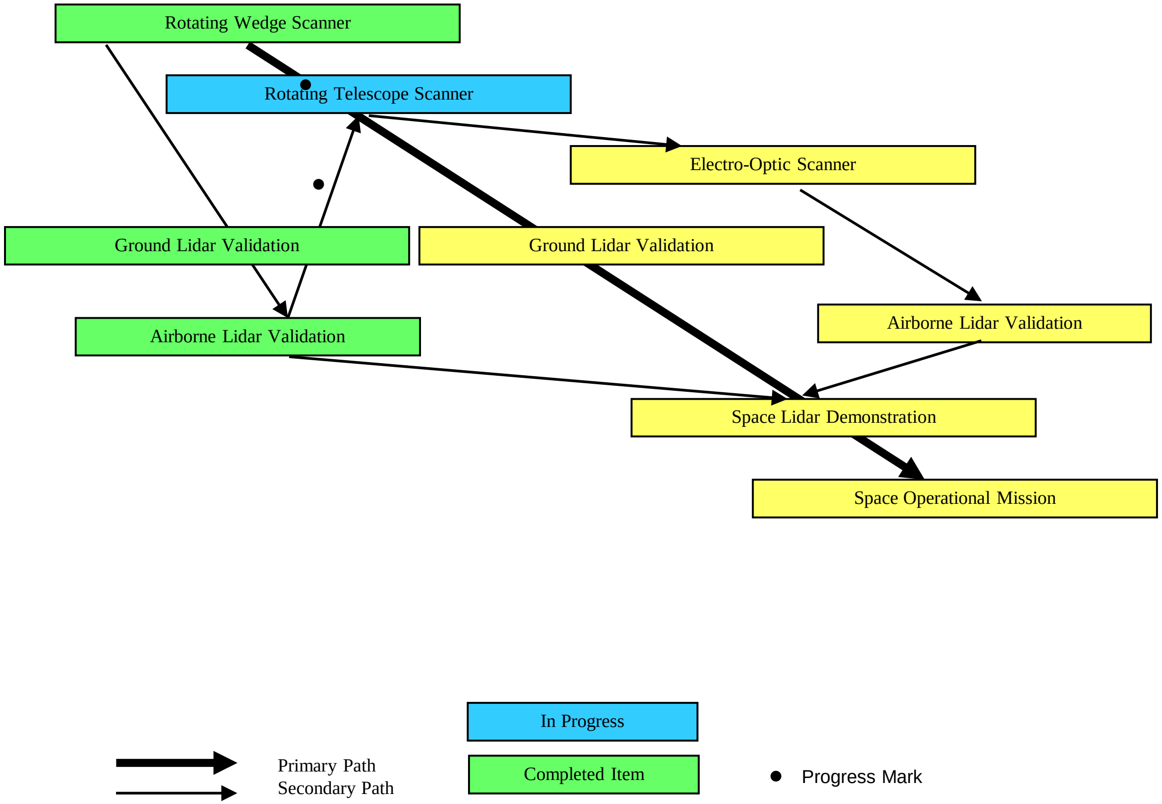
Gentry (2003)

Laser Roadmap – Coherent Subsystem



Amzajerdian, Kavaya (2003)

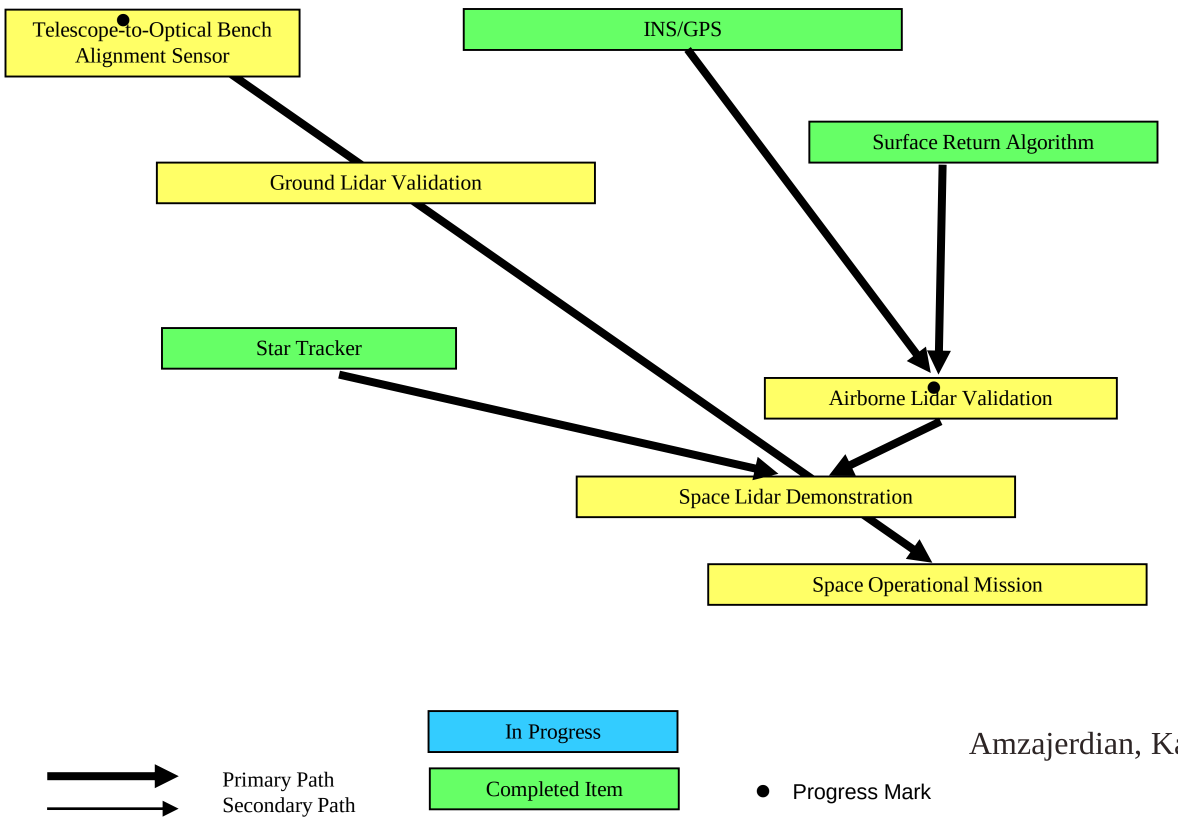
Scanning Subsystem – Coherent Subsystem



Amzajerdian, Kavaya (2003)

Pointing Roadmap –Coherent Subsystem

Pointing target performance
- 0.2 degrees pre-shot pointing knowledge
- 50 μrad final pointing knowledge



Amzajerdian, Kavaya (2003)

Additional Component Technology Roadmaps

- See Reference 2

Conclusions

- Technology development comes first
  - Lasers
  - Detectors
  - Low-mass telescopes
  - Scanners
  - Momentum compensation)
- Data requirements vs. benefits trades may reduce technology development time
- Architecture concepts – some near term areas
  - Hybrid reference design
  - Calibration and validation
  - Mission and spacecraft alternatives
  - Impacts on data products from atmospheric properties, DWL alternatives, and spacecraft mechanics

Technology Readiness Time Scale

- Funding levels, technology advances
- Longest lead time estimates
  - Flight qualified lasers – 4 years
  - Electro-optic scanners – up to 6 years