# ASEN-6519 Lidar Remote Sensing

# Lecture 01. Introduction to Lidar Remote Sensing Class


## Instructor: Xinzhao Chu

Associate Professor, Department of Aerospace Engineering Sciences (AES)

Fellow, Cooperative Institute for Research in Environmental Sciences (CIRES)


Fall 2008 @ University of Colorado at Boulder

# LIDAR: What and Why?

**LIDAR stands for Light Detection and Ranging, commonly known as Laser Radar.**

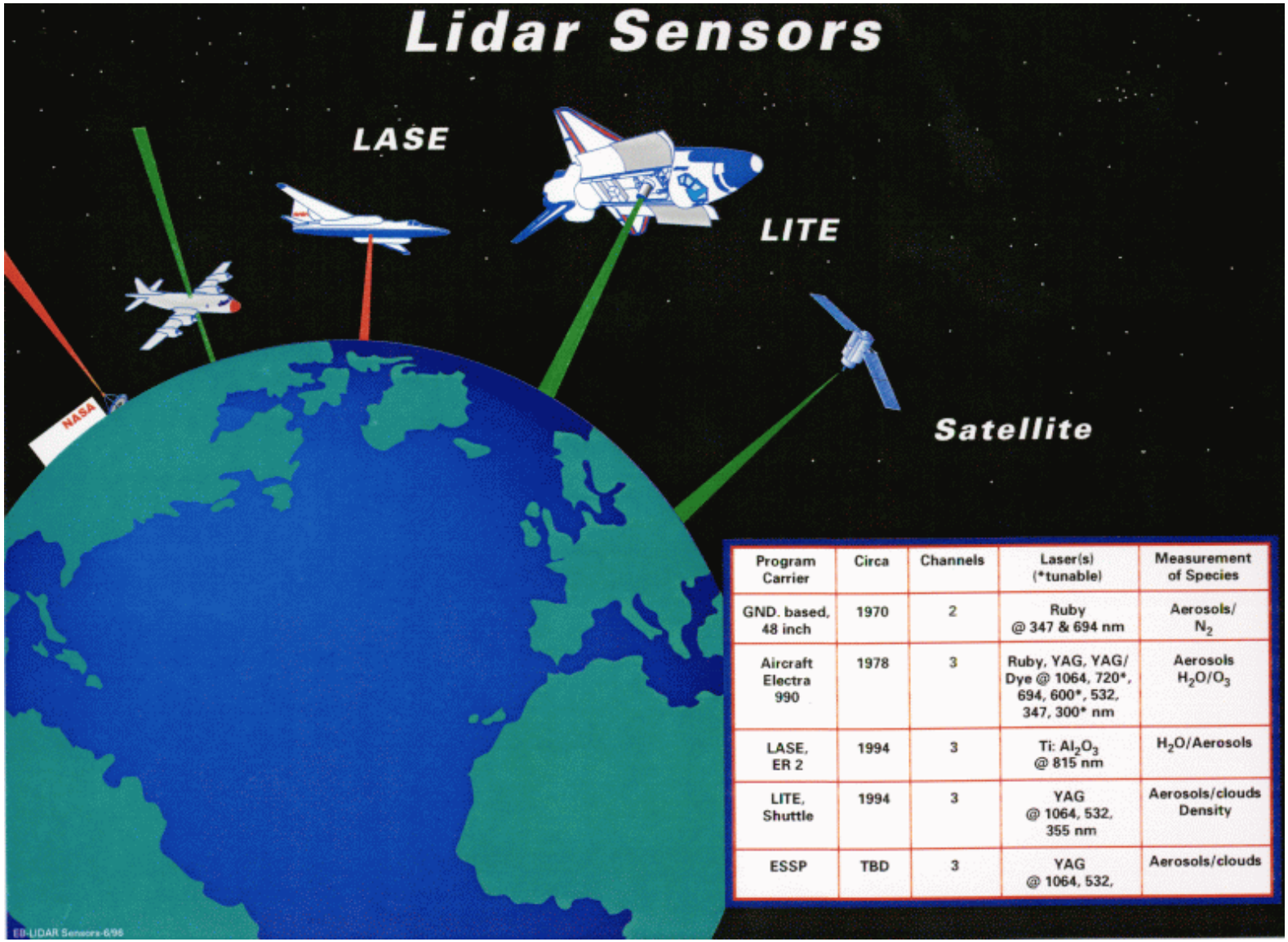
**Lidar is not only replacing conventional sensors, but also creating new methods with unique properties that could not be achieved before.**

**Lidar is extremely useful in atmospheric and environmental research as well as space exploration. It also has wide applications in industry, defense, and military.**

# LIDAR: Light Detection And Ranging

- **Send light to the atmosphere**
- **Record light scattered by the atmosphere as function of time**
- **Convert time of flight to distance (1 ms ~ 150 km)**

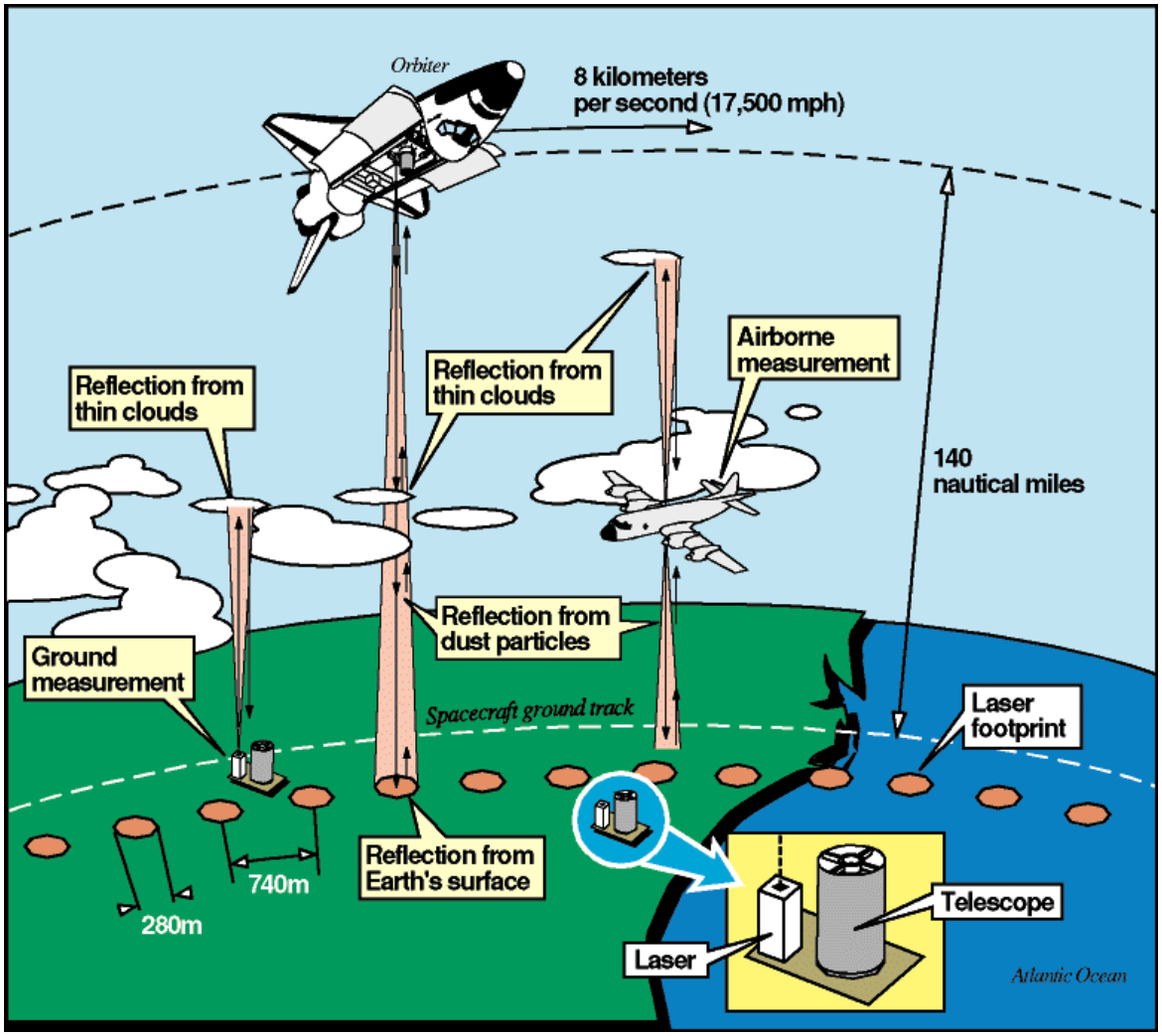
# Lidar from Ground to Space



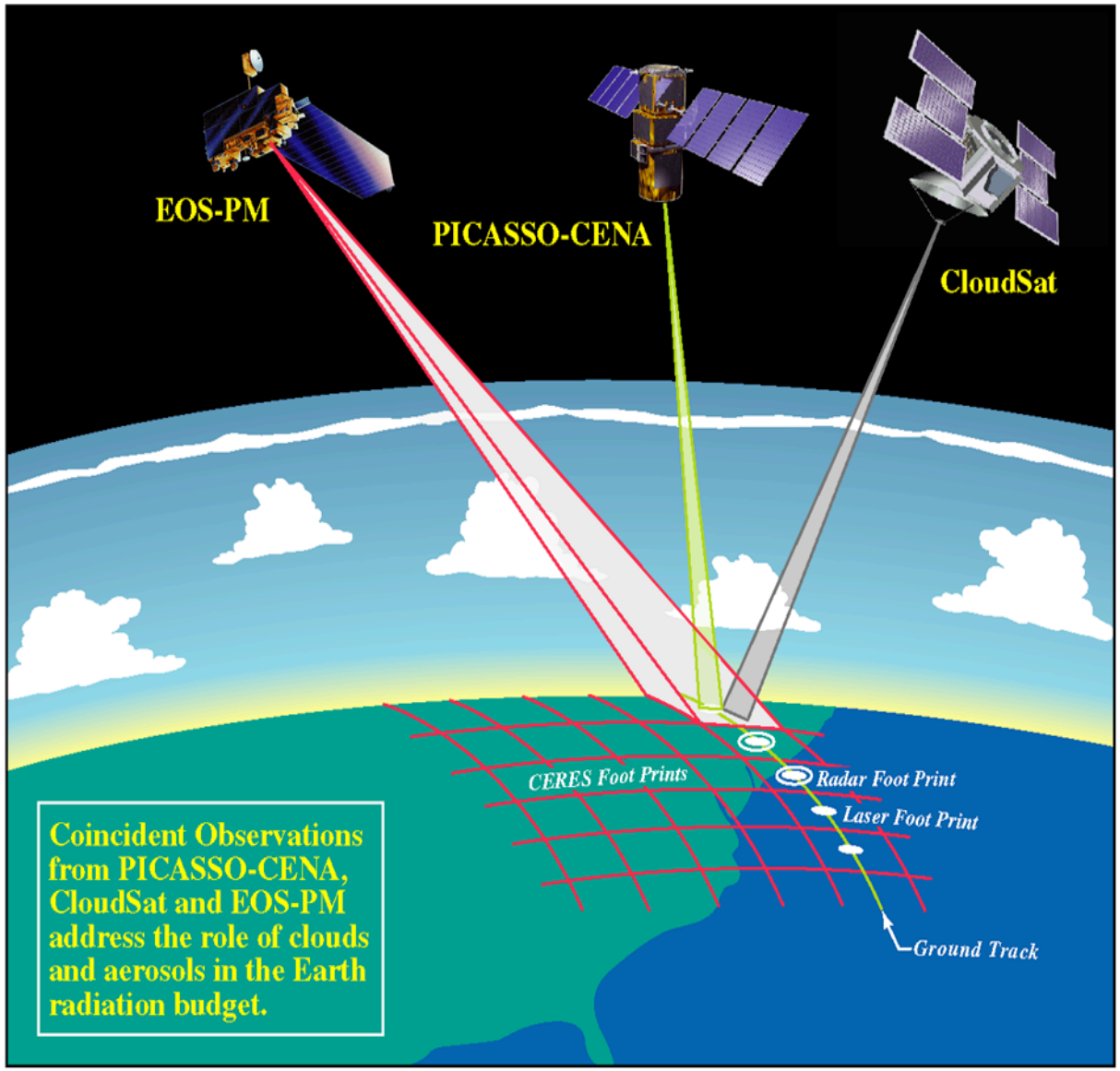

| Program Carrier | Circa | Channels | Laser(s) (*tunable) | Measurement of Species |
|---|---|---|---|---|
| GND. based, 48 inch | 1970 | 2 | Ruby @ 347 & 694 nm | Aerosols/ $N_2$ |
| Aircraft Electra 990 | 1978 | 3 | Ruby, YAG, YAG/ Dye @ 1064, 720*, 694, 600*, 532, 347, 300* nm | Aerosols $H_2O/O_3$ |
| LASE, ER 2 | 1994 | 3 | Ti: $Al_2O_3$ @ 815 nm | $H_2O$/Aerosols |
| LITE, Shuttle | 1994 | 3 | YAG @ 1064, 532, 355 nm | Aerosols/clouds Density |
| ESSP | TBD | 3 | YAG @ 1064, 532, | Aerosols/clouds |

# NASA LITE Mission

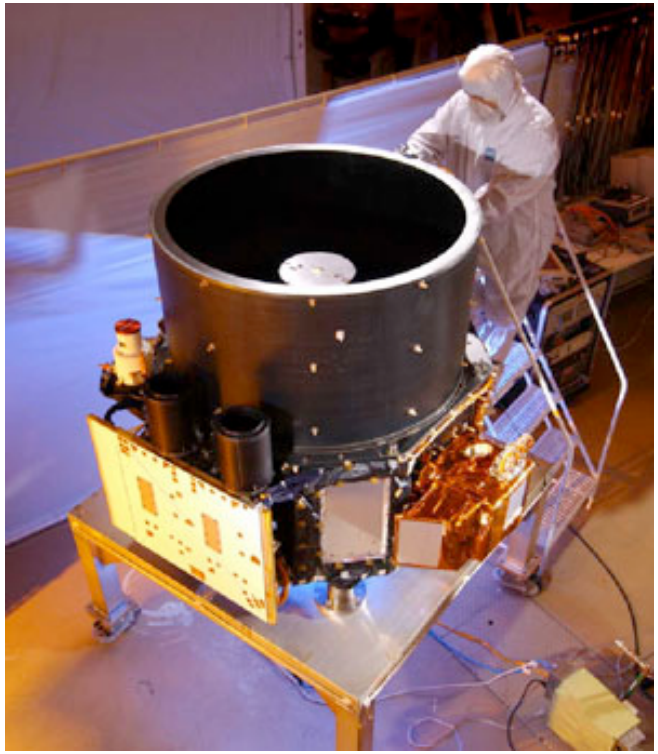
## Lidar aboard Space Shuttle Discovery

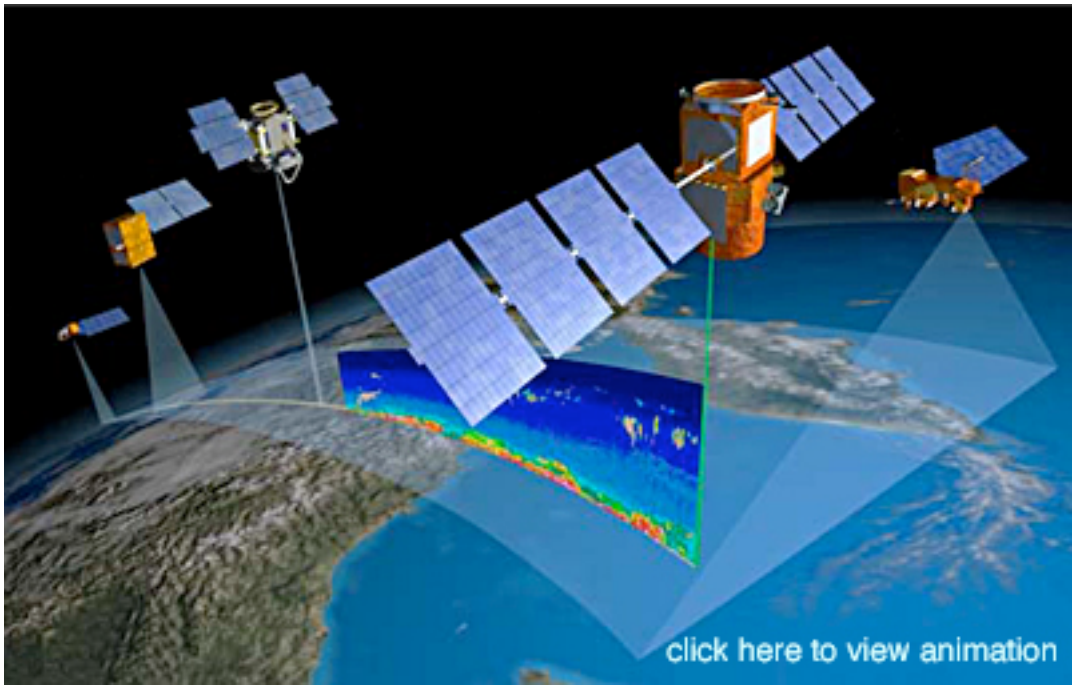


# Lidar aboard Satellites



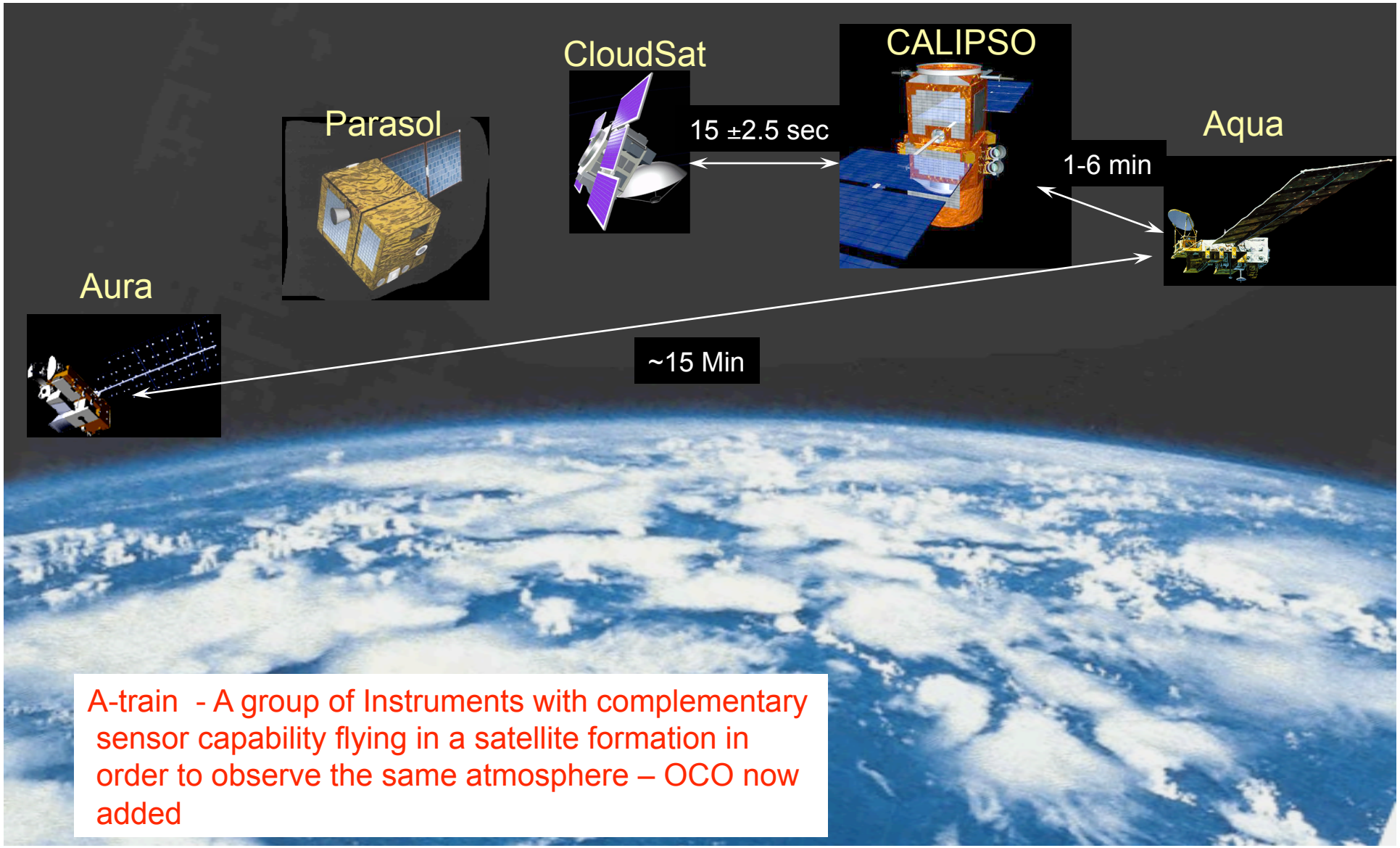
# CALIPSO: Lidar on Satellite





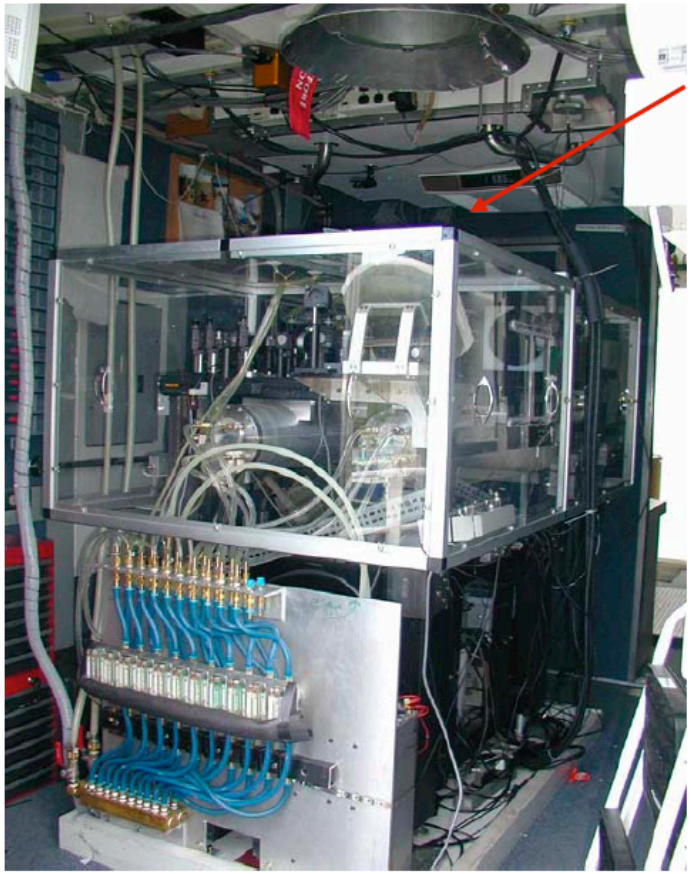

http://www-calipso.larc.nasa.gov/

# Aqua (A) Train for Multiple Observations

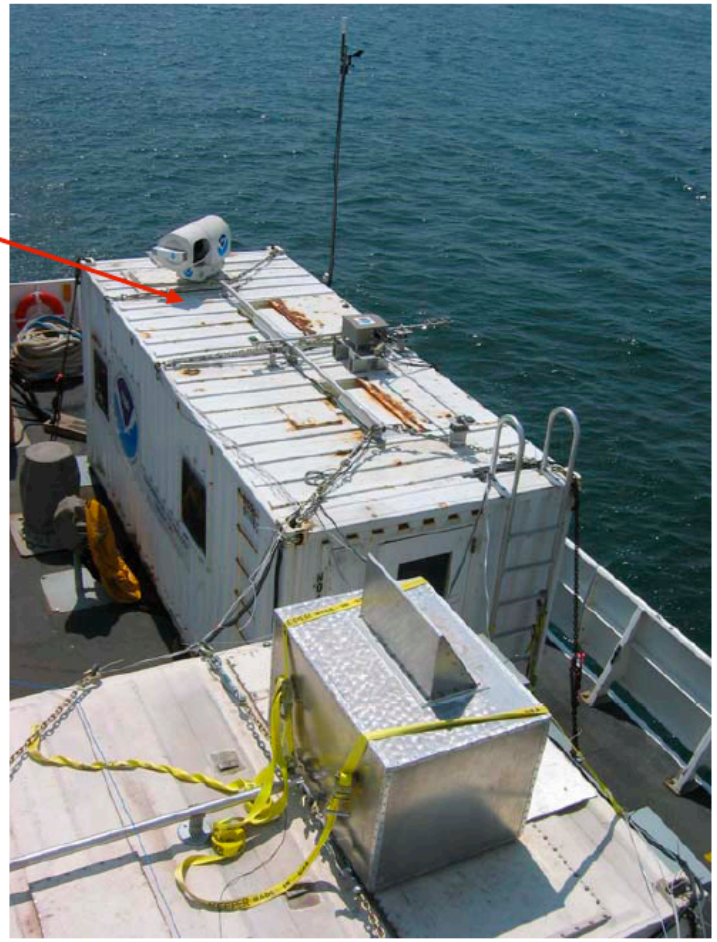



A-train - A group of Instruments with complementary sensor capability flying in a satellite formation in order to observe the same atmosphere – OCO now added

# NOAA ESRL Lidars on Ocean



- Mini-MOPA
- HRDL
- OPAL
- TOPAZ
- DABUL
- Fish Lidars
- TUV
- CODI
- TEAC0
- ABAeL



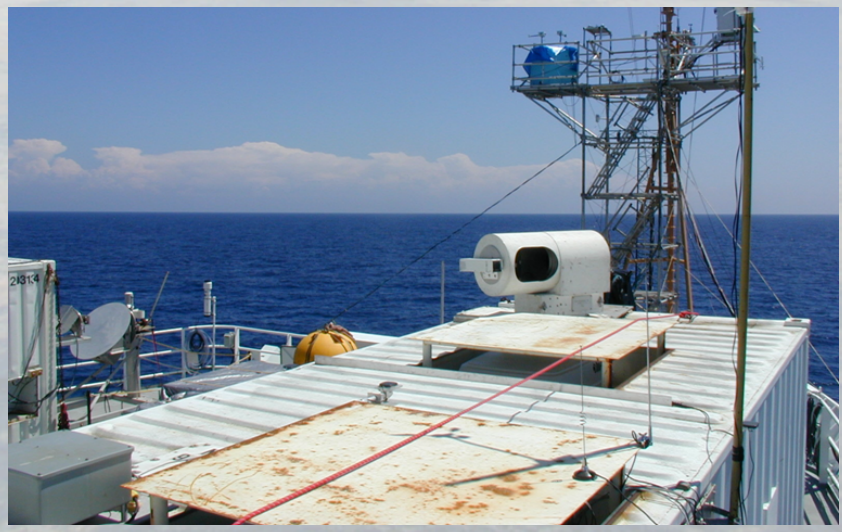
# Basic Lidar measurements


- Chemical distributions (ozone, water vapor, NH3, CO2)
- Cloud properties
- Aerosol measurements
- Low level mean winds
- Residual winds
- Turbulence, general dynamics

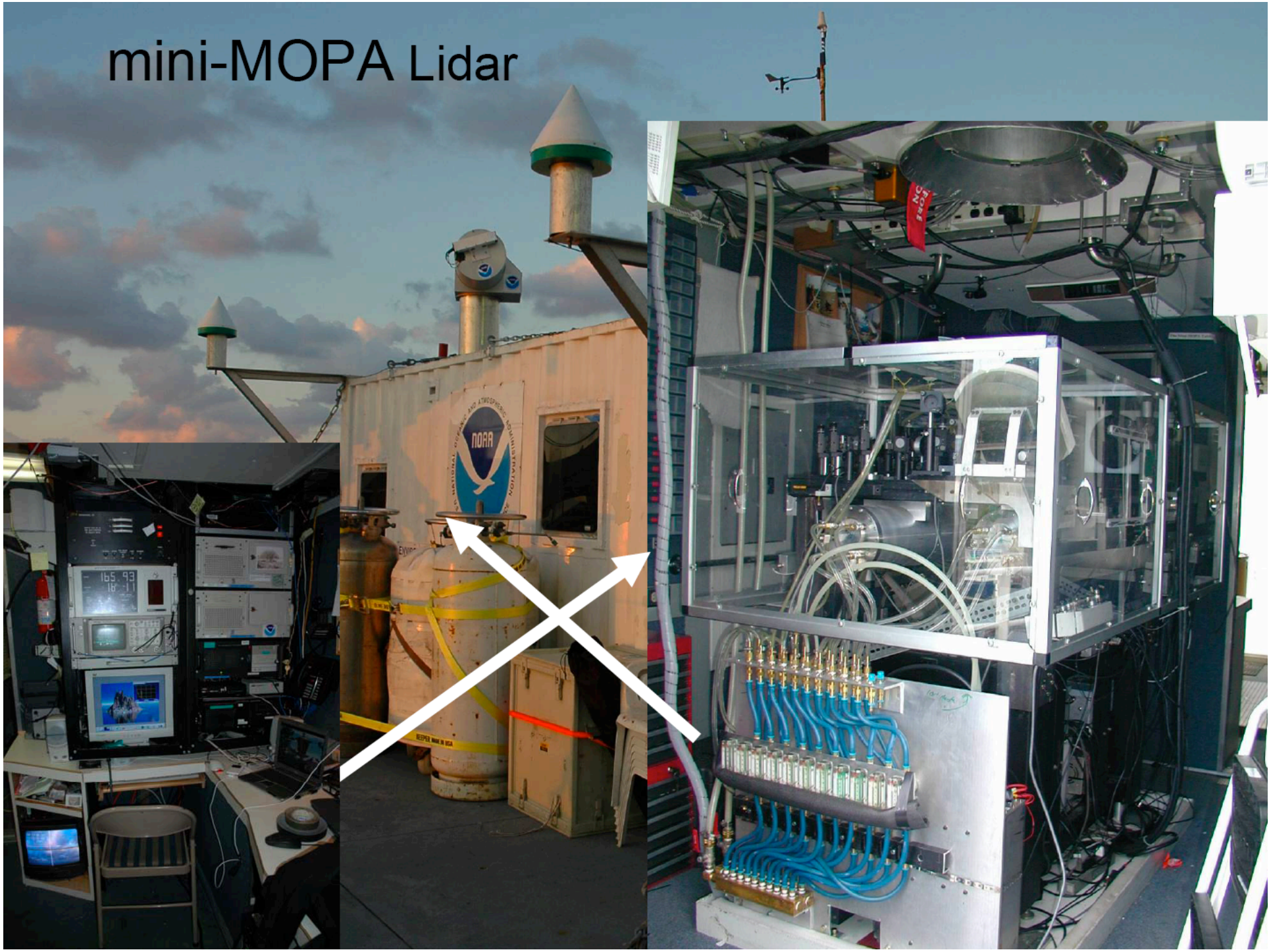
**Instruments have been mounted on research ships for sea based operation**

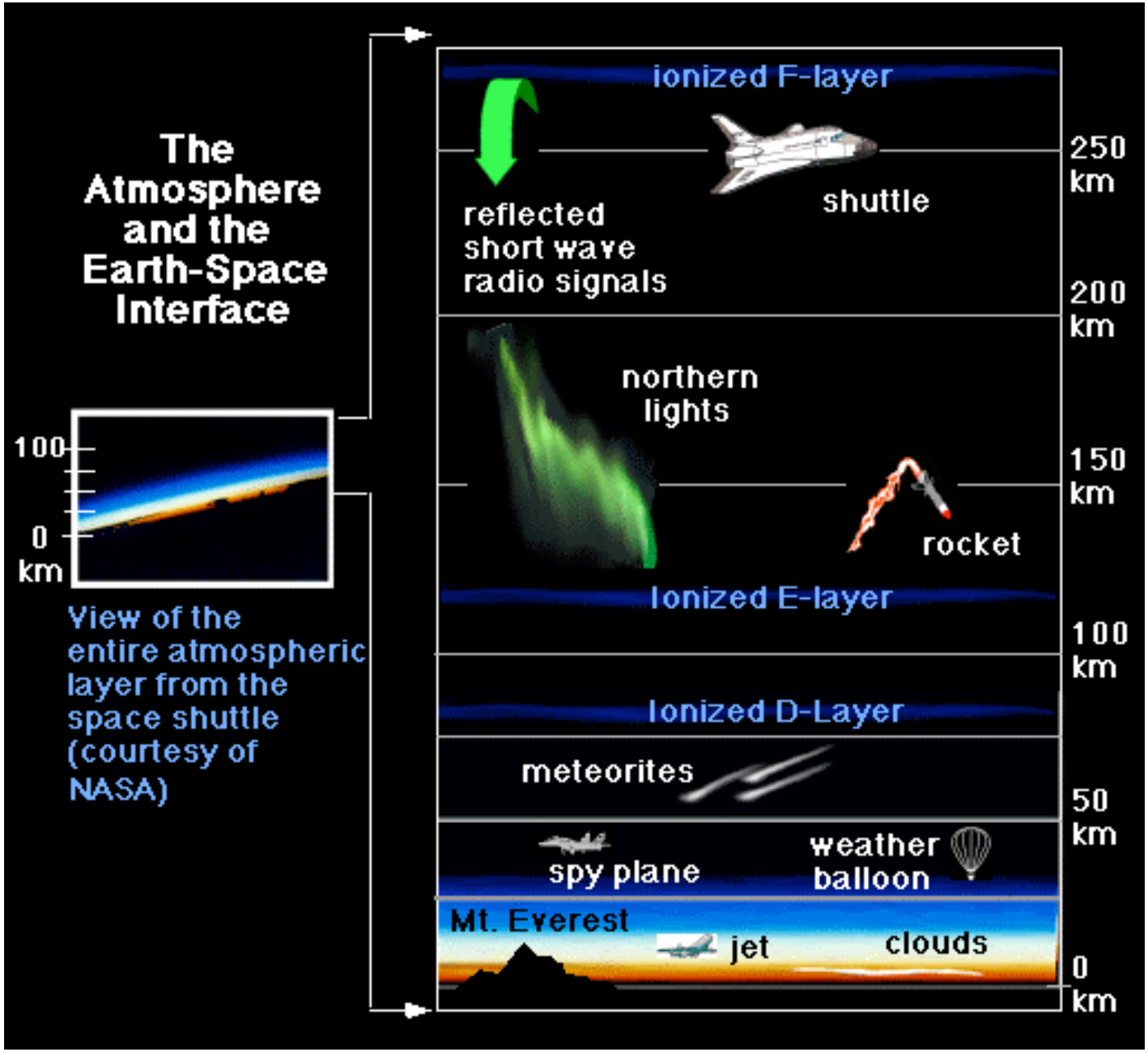
**Challenges include:**

- Sea salt corrosive environment
- High vibration
- Platform motion & orientation
- Low frequency accelerations – stability issues
- Big waves and leaky seatainers



# mini-MOPA Lidar

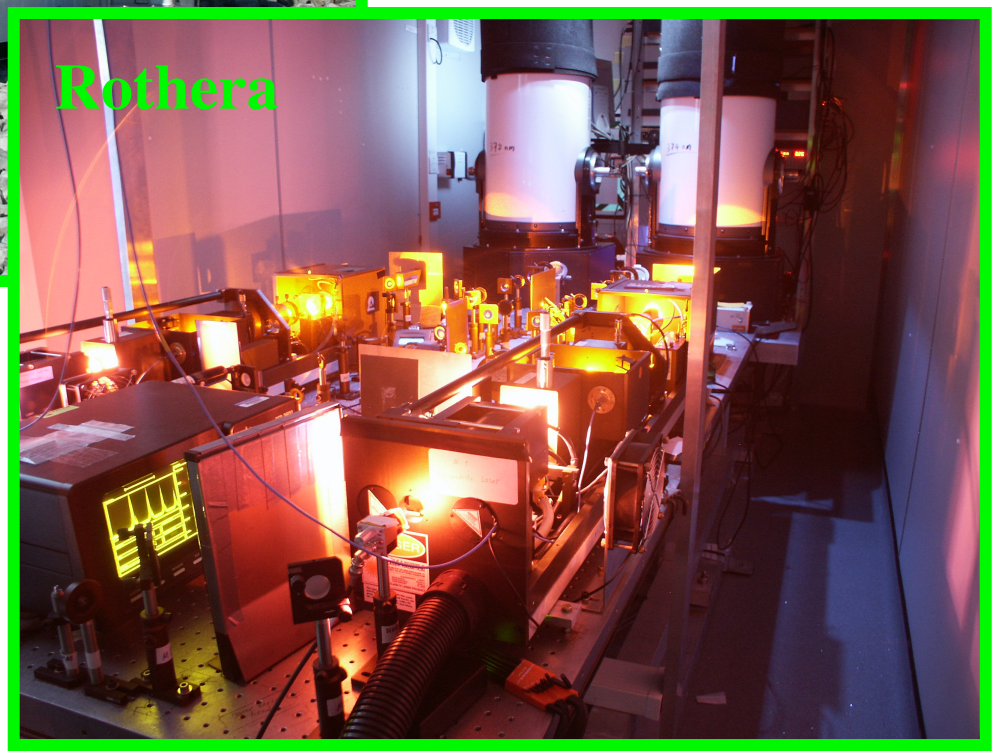



The Atmosphere and the Earth-Space Interface
100
0
km
View of the entire atmospheric layer from the space shuttle (courtesy of NASA)
ionized F-layer
reflected short wave radio signals
shuttle
250 km
200 km
northern lights
150 km
rocket
Ionized E-layer
100 km
Ionized D-Layer
meteorites
50 km
spy plane
weather balloon
Mt. Everest
jet
clouds
0 km



# Airborne Fe Boltzmann Lidar

# Groundbased Lidar at the South Pole

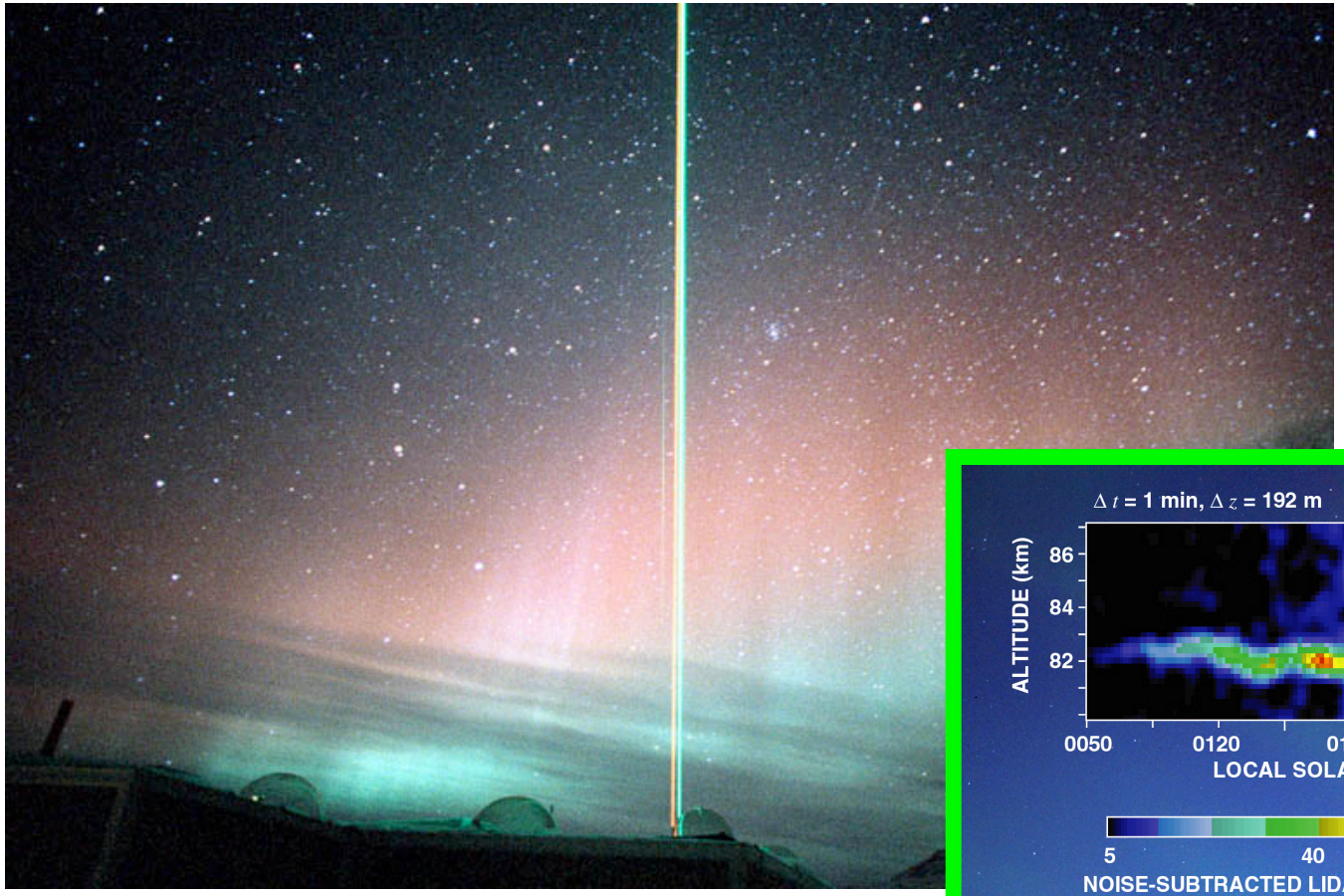



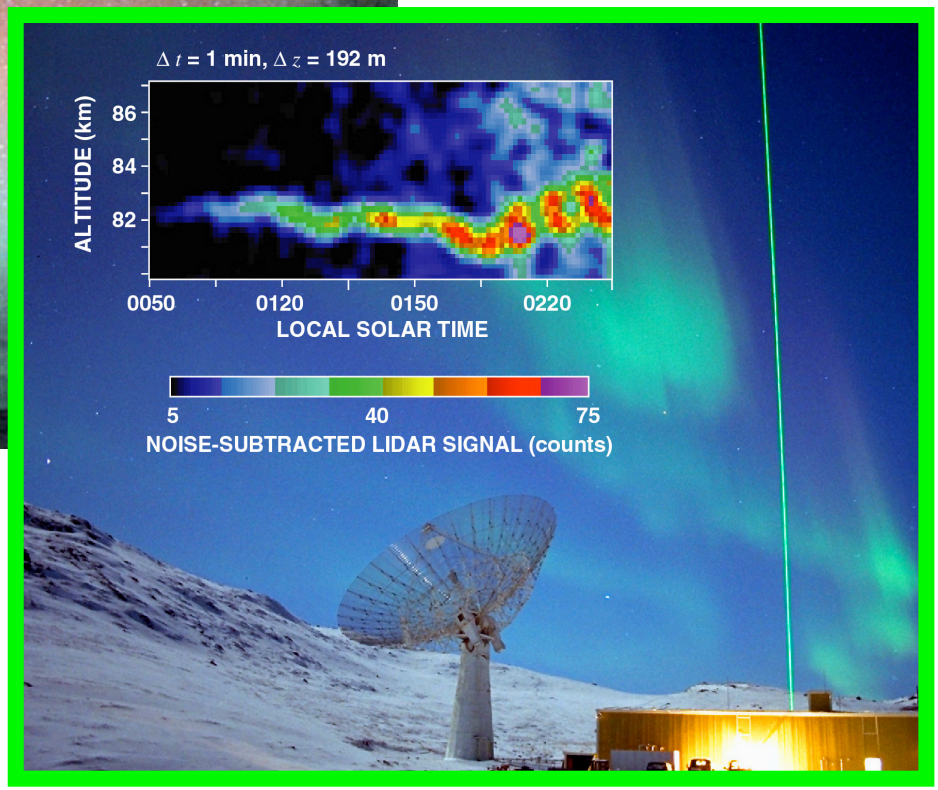

# Containerized Lidar at Rothera, Antarctica

# Containerized Lidar at Svalbard

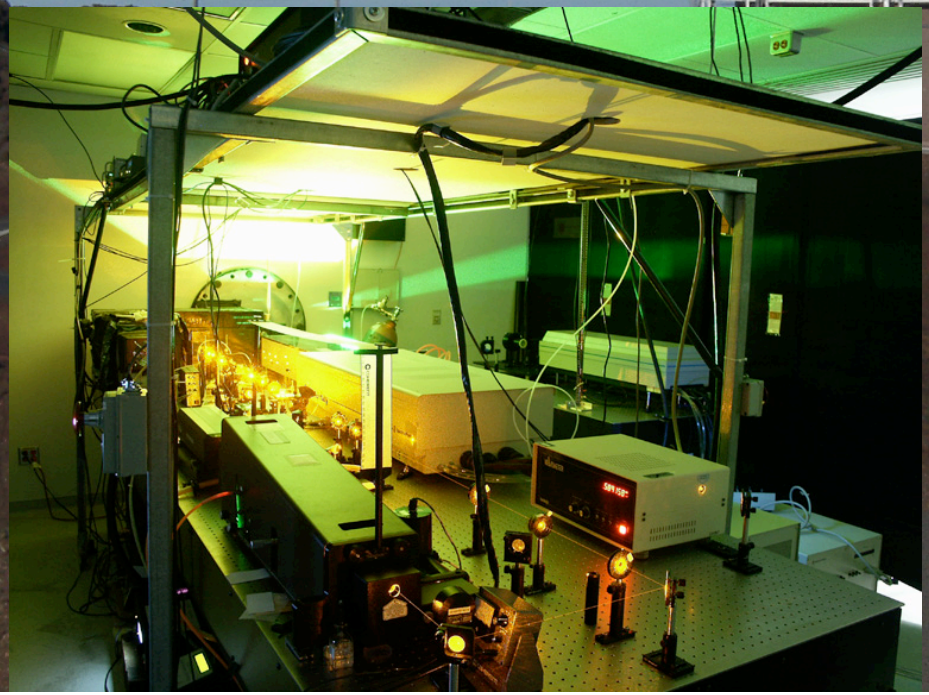
# Andoya Rayleigh & Na Lidars

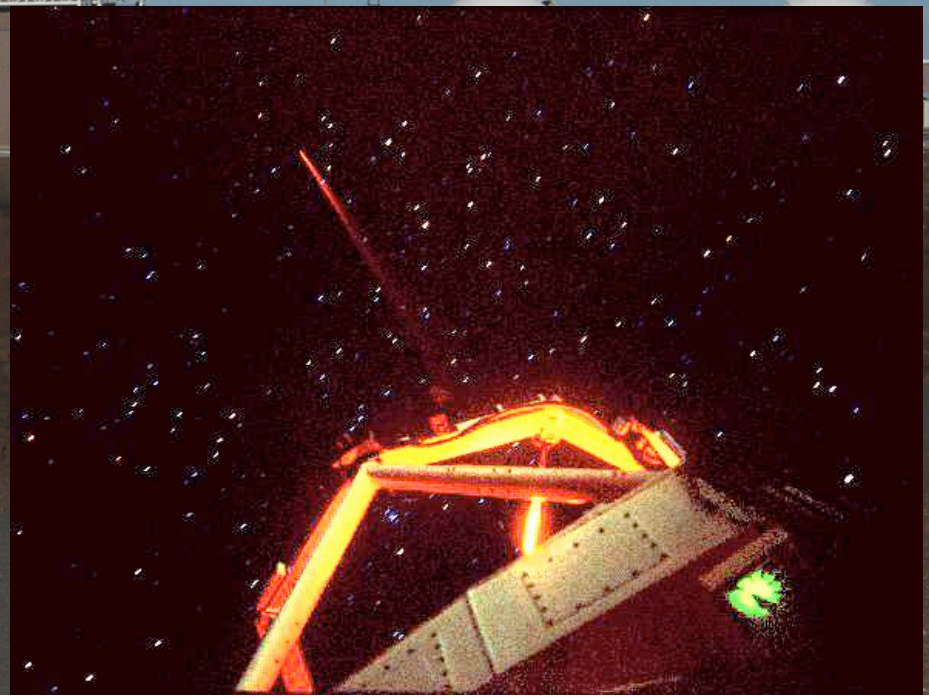
# Sondrestrom Rayleigh Lidar



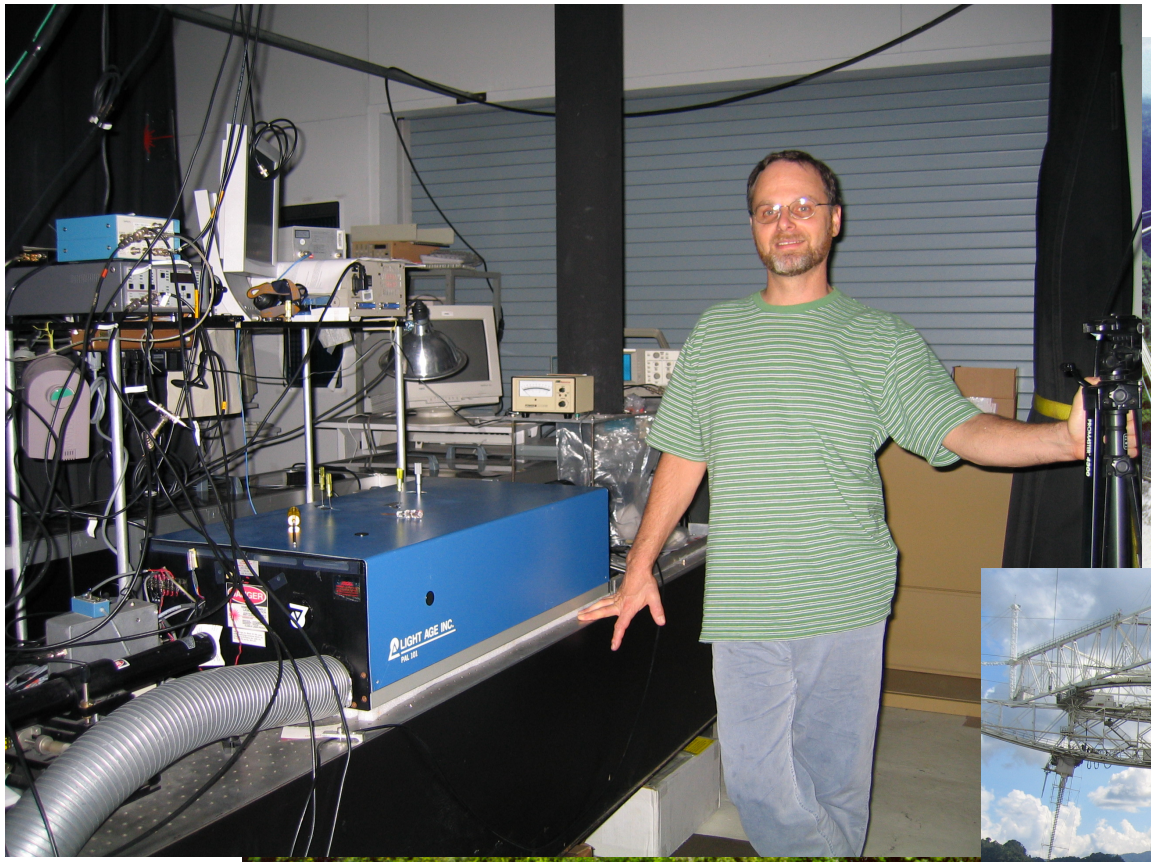


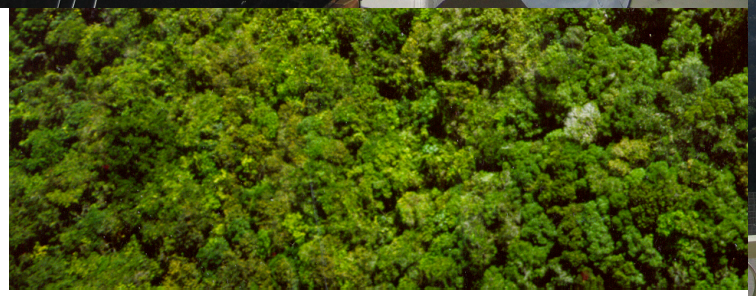
# Large-Aperture Na Doppler Lidar at SOR, NM and Maui, HI





# Arecibo Observatory K Doppler Lidar



# Lidar Course Objectives

1. A comprehensive, yet easily understandable, up-to-date overview of lidar principles, technologies, and applications;

2. Approaches for lidar simulation, lidar sensitivity and error analysis, lidar data retrieval, and lidar system design to quantitatively analyze lidar system performance and measurement errors;

3. Opportunities to see and possibly operate the real state-of-the-art lidar systems and make connections to lidar experts in the nation and world.

# Textbook and Reading Materials

**Textbook:**

"Laser Remote Sensing" (2005)
edited by Fujii and Fukuchi

**Major Reference Books:**

"Lidar" (2005)
edited by C. Weitkamp

"Laser Remote Sensing: Fundamentals and Applications" (1984)
by Raymond Measures

**Other References:**

"Proceeding of 24th ILRC" and other journal papers

# Course Format

1. PPT presentation in classroom

2. Lecture notes posted at the class webpage:

http://cires.colorado.edu/science/groups/chu/classes/

3. Homework Reading Reports over reading materials

4. Homework Projects of lidar simulation and data retrieval

5. Final project integrating reading, design, and simulation together, with class presentation and final written report

# Grading Policy

20% Homework Reading Reports: your understanding to lidar principles, technologies, and applications

60% Homework Projects:

(1) Lidar simulations (e.g., range-resolved or non-range -resolved lidar photon counts, error analysis)

(2) Lidar data retrieval and error analysis (e.g., Na density, Doppler temp and wind, Boltzmann and Rayleigh temperature, coherent wind, HSRL aerosol, DIAL, or Raman lidar data)

(3) Lidar design and performance analysis

20% Final Project: Select one type of lidars and go through principle, design, simulation, error analysis, application

100-point grading system for reports and projects

# Potential Final Projects

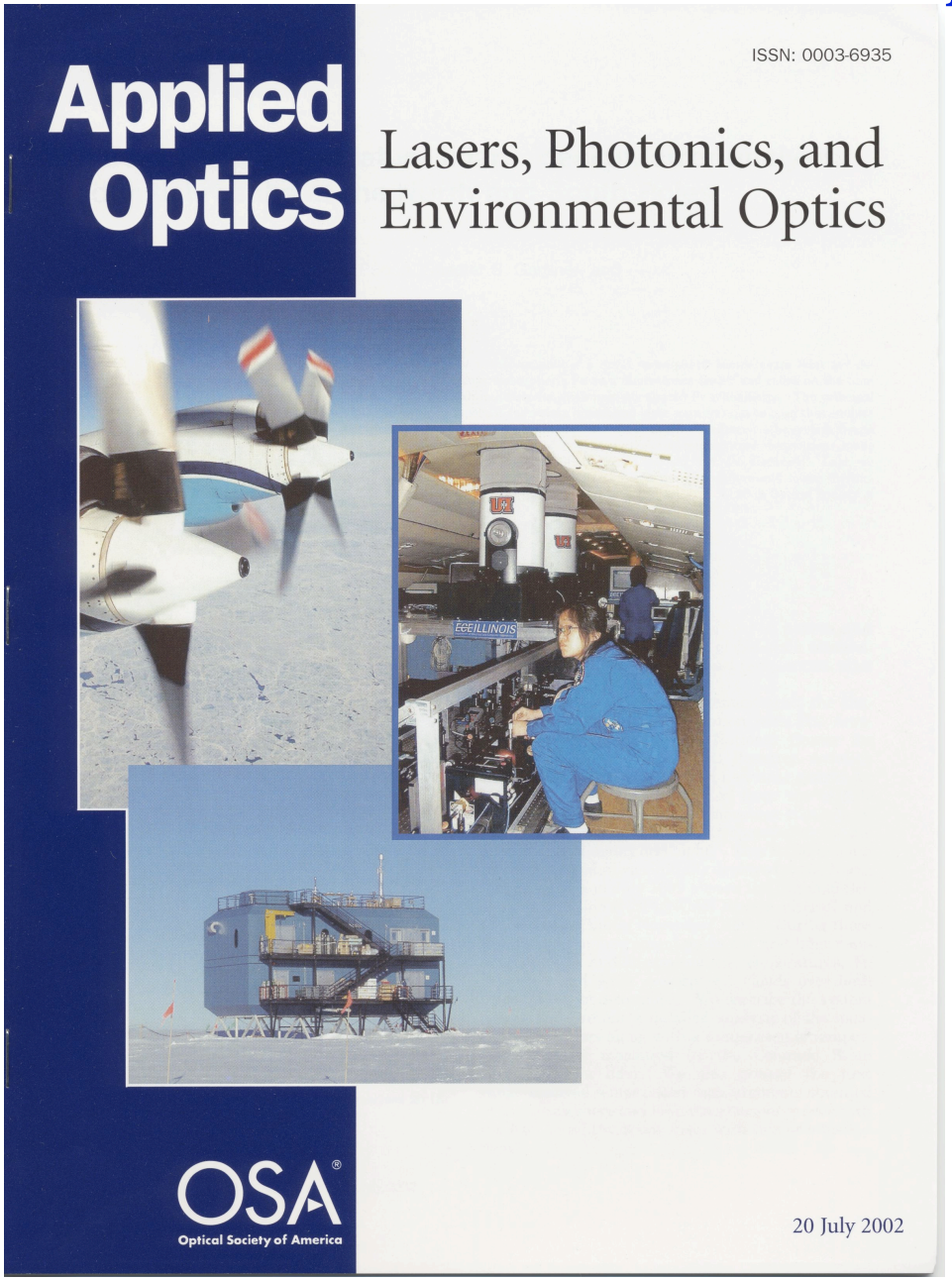
1) Resonance Fluorescence Doppler lidar
2) High-spectral-resolution lidar
3) Direction-detection wind lidar (or with edge filters)
4) Coherent Doppler lidar
5) Laser altimeter (including fish lidar)
6) Raman lidar
7) Differential absorption lidar (DIAL)
8) Aerosol polarization lidar
9) Rayleigh/Mie lidar
10) Fluorescence lidar ……

- Overview of principles, history, and current status
- Design of a lidar system
- Simulation of expected lidar signals
- Sensitivity or error analysis
- Applications

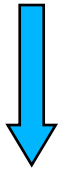
# How to study this course?

1. Read books and lecture notes prior to classes, especially if lack of background
2. Listen to the lectures and try to understand the most in classes
3. Review lecture notes and read books and materials
4. Do projects to apply learned skills and check concepts
5. Ask and discuss with instructor and classmates to get clear concepts
6. Visit instructor's research group to look at real instruments and real applications

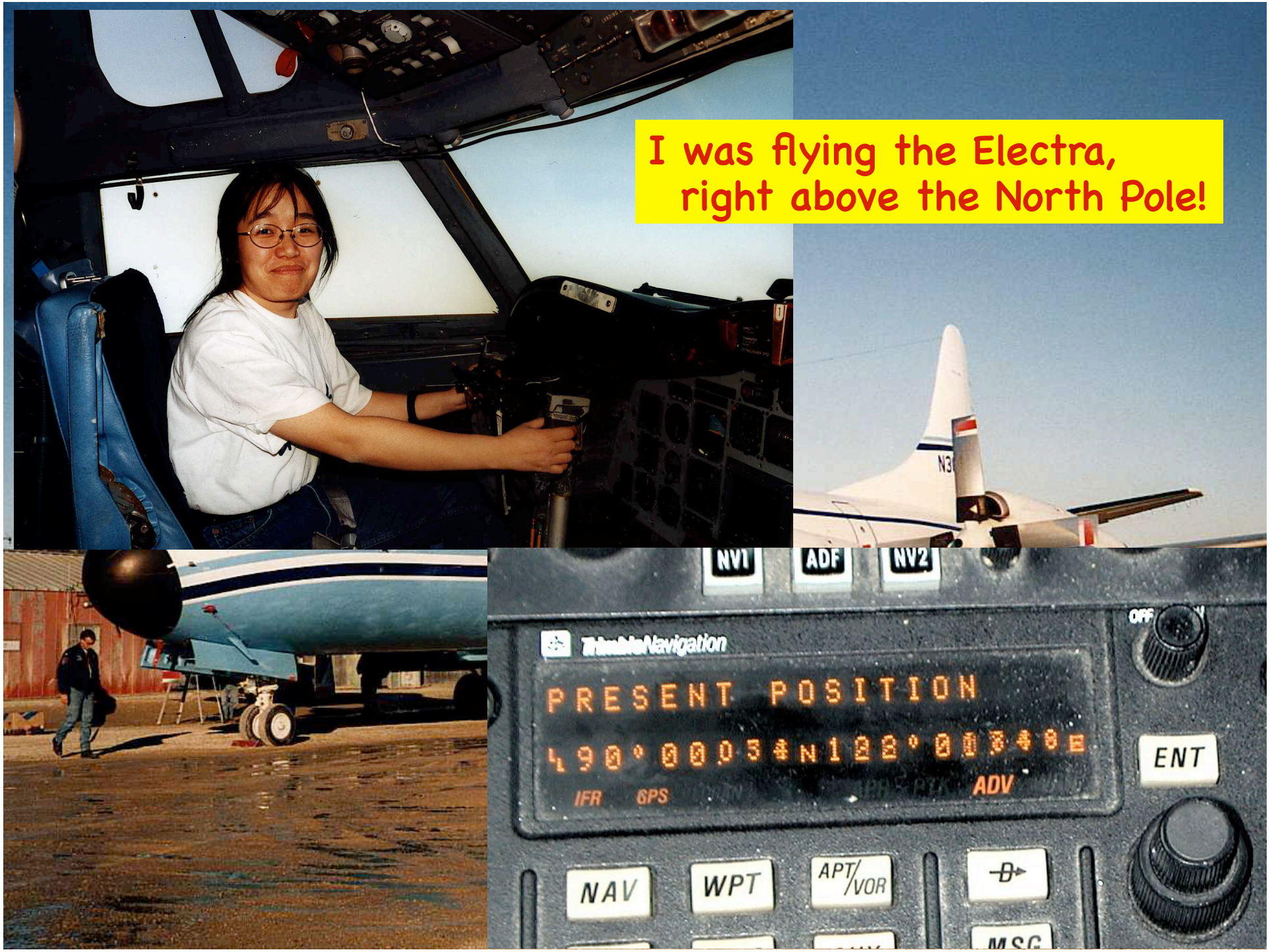
# Pole-to-Pole Expedition



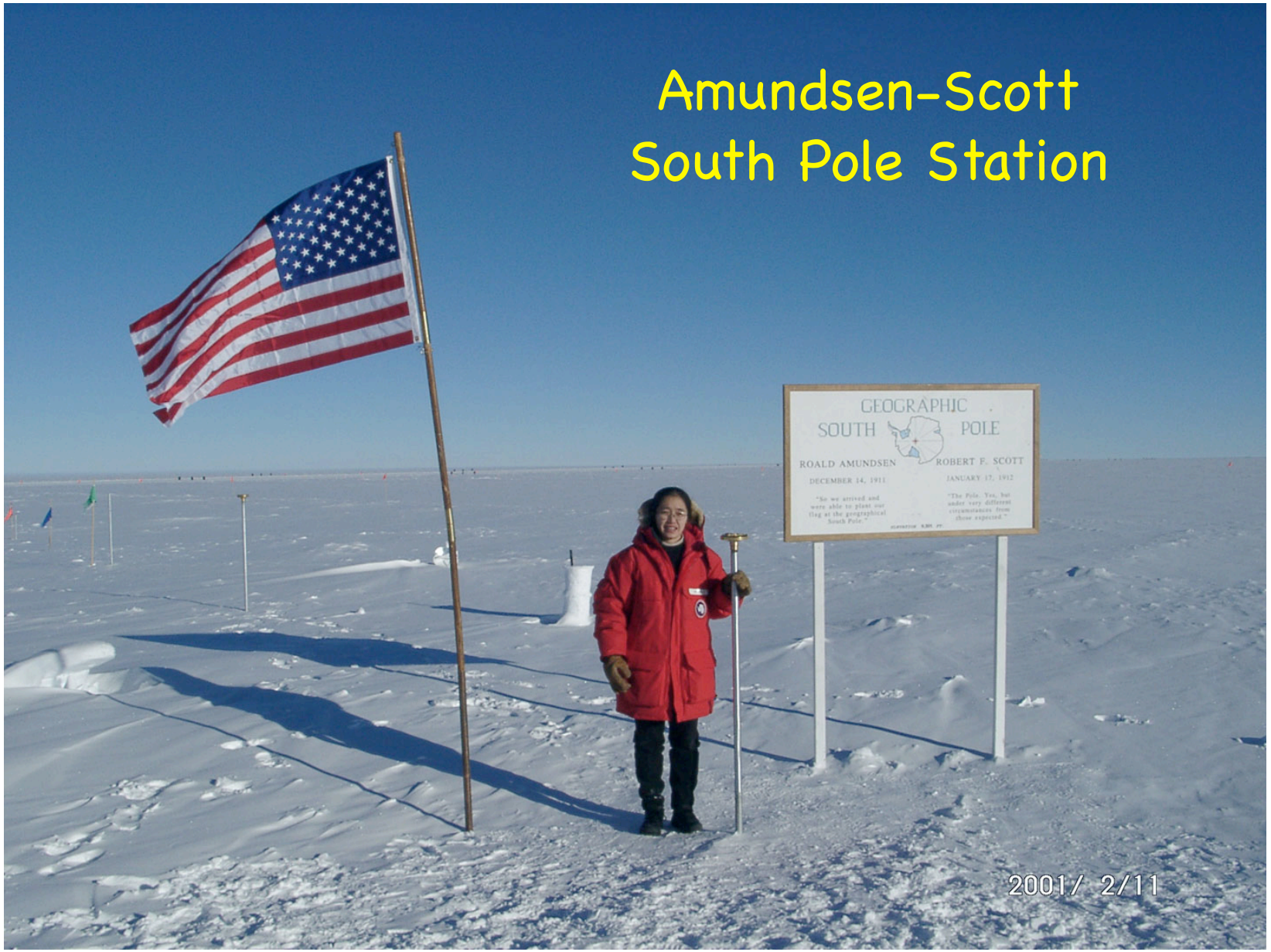

21 June 1999
Over the North Pole



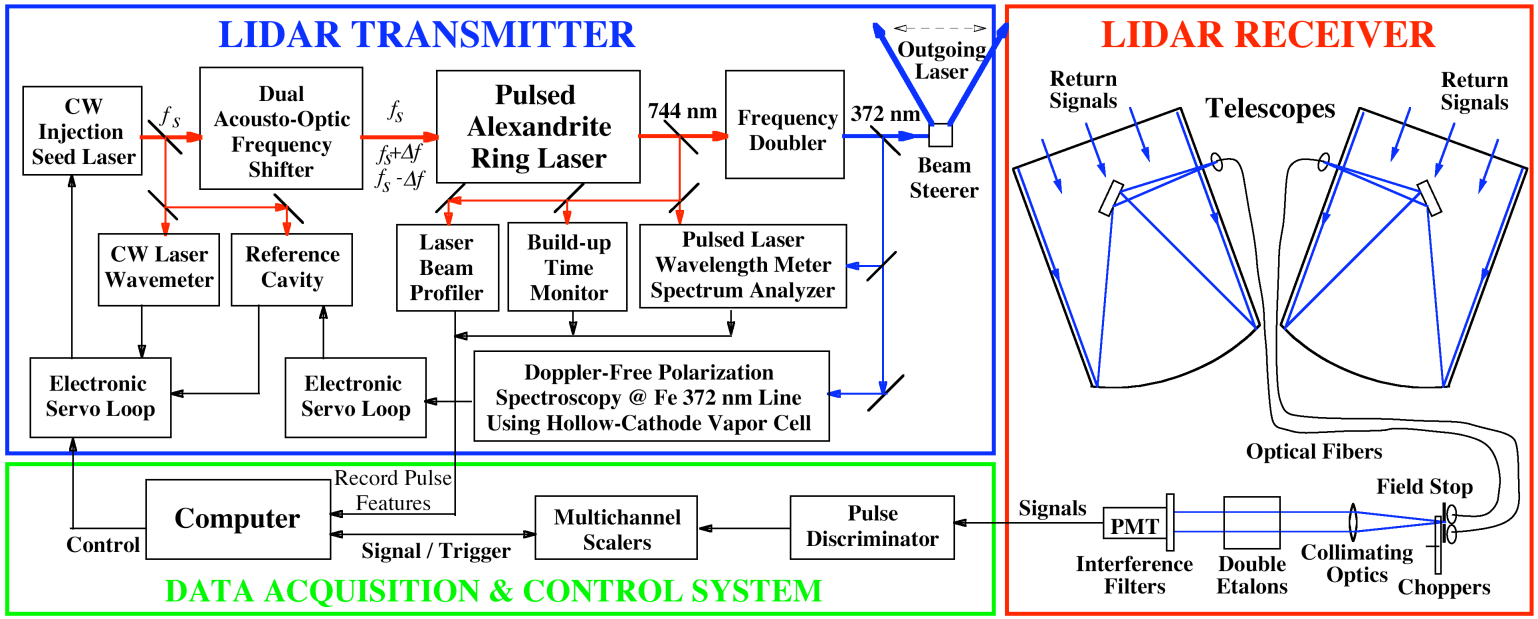
24 November 1999
At the South Pole


I was flying the Electra,
right above the North Pole!
NV1
ADF
NV2
OFF
PRESENT POSITION
IFR
GPS
ADV
ENT
NAV
WPT
APT/VOR
MSG

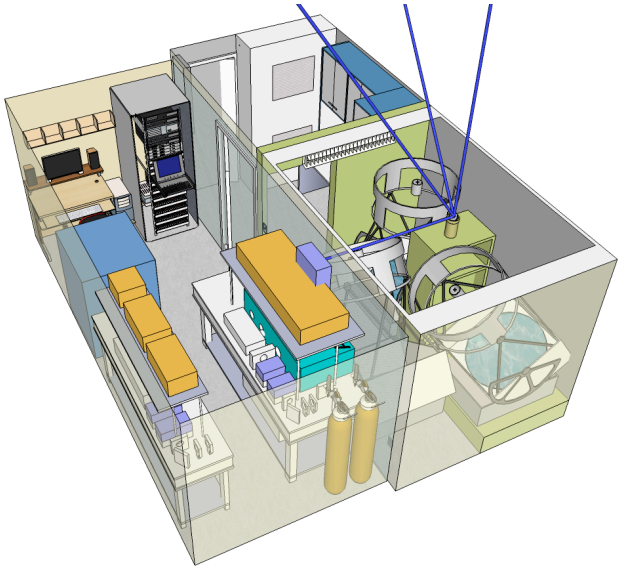
# Pole-to-Pole Expedition: South Pole



# Concept of MRI Doppler Lidar




## (NSF and UCB Major Research Instrumentation)

# Summary

**We expect an exciting adventure through the wonderful "lidar remote sensing" field …**

**Hope you will stay with us in the journey …**

**Let us work together to make advancement and contribution to lidar and lidar application.**

Reference Reading Materials

IntroRemoteSensing.pdf and IntroLidar.pdf (at website)

Chapter 1 of "Laser Remote Sensing" textbook