Lightweight Deployable UV/Visible/IR Telescopes

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***Abstract*-The vision of the Earth Science Enterprise (ESE) of the National Aeronautics and Space Administration (NASA) established a variety of science challenges for the next 20 years, relating to predictions of weather, climate, and foreseeable changes in the Earth's environment. In this paper, we discuss the attendant needs for space-based, lightweight deployable telescopes for a variety of science challenges. In addition, we suggest some strategies for deploying the necessary assets.**

I. INTRODUCTION

The ESE vision encompasses a wide variety of instrument, data information and platform technologies that enable an even broader set of science and application needs. In order to determine how to achieve this vision, the Enterprise has commissioned several workshops to capture the needs of the science and application communities and derive the requisite technologies. The goal of the workshops was to determine the science needs and how those manifested into technology requirements. In addition, the workshop participants devised a strategy for maturing those technologies that included validation necessary for the technology to become available for a science mission. The workshops were comprised of scientists and technologists in each of several disciplines. The specific workshop topics were determined by examining the broad set of science and application needs and finding common technology drivers.

One resultant technology area is lightweight, deployable telescopes for science measurements in the infrared (IR), visible and ultraviolet (UV) region of the electromagnetic (EM) spectrum. The foci of science measurements discussed in this paper are those for which deployable telescopes are enabling technologies:

- Differential absorption lidar for high vertical resolution mapping of tropospheric ozone, CO_2, water vapor, NO_2, and aerosols
- Direct detection and coherent lidar observations of tropospheric winds from space
- High resolution imaging and spectroscopic observations from high orbits (GEO, LI, and L2)

The first step towards realizing NASA's Earth Science vision is to devise a strategy that carries the enabling technologies through the lifecycle of conceptual study, risk reduction and finally validation. These technologies and a notional strategy are described in the following sections.

II. REQUIREMENTS DEVELOPMENT PROCESS

The process for enabling science measurements for the ESE is that of a systematic flow-down from science needs to implementation options that ultimately lead to specific, enabling technology requirements. In most cases, science measurement needs can be accommodated with several instrumentation alternatives, typically leading to diverse technology requirements. Generally, the ESE will narrow the resultant measurement capability down to one implementation via a competitive process. As part of the maturation of a given implementation, though, is a process of balancing options within the implementation to, in a fashion, optimize the requirements of the component technologies that comprise the implementation.

For example, the measurement of chemical constituents in the Troposphere can be achieved via an active optical approach, i.e., a differential absorption lidar (DIAL) or a passive optical approach using a radiometer sensitive in the UV region of the EM spectrum. In the case of the active approach, in order for the science retrieval algorithms to extract the concentration of chemical species a minimum signal to noise ratio must be achieved. The implementation calls for collecting photons from the transmitted laser pulses that are backscattered from the atmospheric constituents. One of the most fundamental trade-space that then unfolds is of transmitter power versus receiver efficiency. The prudent approach to enabling this measurement need is to proceed along parallel technology developments in creating higher power laser transmitters and also higher efficiency receivers. The emphasis for this paper is on the path of increasing the efficiency of the receiver, and specifically by increasing the aperture size of the telescope to improve sensitivity to backscattered photons. Table 1 lists the measurement needs and the baseline technology requirements. The specific technology drivers will be discussed in section III.

In the case of the science needs for thermal IR imagers, the strategy for technology development does not require a multi-faceted trade-space. Instead, given the need for high-spatial and temporal imaging (see Table 1 for a description of these measurement requirements), the technology drivers are the size of the aperture and the surface figure. The technology drivers for this science measurement need will be discussed in detail in section IV.

TABLE 1
SUMMARY OF SCIENCE NEEDS

Science Need	Resolution ΔZ [km]	ΔX [km]	Accuracy %	Wavelength µm	Telescope Diameter m	Figure	Orbit km/orbit
O_3	2.5	200	10	0.3	>3.0	$\lambda/1$	500/polar
CO_2	3.0	500	0.5	1.6/2.0	>3.0	$\lambda/2$	500/polar
H_2O	1.0	100	10	0.82/0.94	>2.5	$\lambda/2$	500/polar
NO_2	3.0	200	10	0.44	>3.0	$\lambda/2$	500/polar
Coherent winds	0.25-1.0	100-300	1m/s	2.0	>2.0	$\lambda/20$	500/polar
Direct winds	0.25-1.0	100-300	1m/s	0.355	>3.0	$\lambda/2$	500/polar
IR Imaging		30-100m		10-14	>2.5	$\lambda/20$	GEO, L1, L2

III. PHOTON COUNTING

Begin text here on details of the technology requirements for the relevant science needs.

IV. IR IMAGING

Begin text here on details of the technology requirements for the relevant science needs.

V. NOTIONAL VALIDATION FLIGHT

Once the fundamental technologies have been matured in the laboratory, the next step in the technology development process is to validate these technologies in a relevant environment, which in the cases of these measurement needs, is space. Generally, though, cost constrains limit the capability that can validated. The prudent approach is to validate just enough of the technology capability to ensure success in a future science mission.

Past flight validation experiments of deployable structures have taught us to expect that critical structural response might change from 1-g to 0-g. Specifically, many tests of macrodynamic behavior (e.g., damping and vibration frequencies) have shown gravity dependency, and recent test of microdynamic behavior indicate the possibility of gravity dependency (in fact, IPEX-II data seems to indicate that 1-g-loading might stabilize some of the thermal pops seen on-orbit).

Unfortunately, at this time it is unclear whether the 0-g environment is better, worse, or nearly the same from a microdynamic performance standpoint. It is possible that some structures will exhibit gravity-independent microdynamic behavior while others might exhibit gravity-dependent behavior. In any event, it is clear that more on-orbit data is necessary to answer these questions.

Continued discussion on validation effort….

VI. CONCLUSIONS

The science needs established by the vision of NASA's Earth Science Enterprise challenge the state of the art for instrument technologies. Incremental, yet revolutionary advances in measurement capabilities and instrument technologies will be necessary to accomplish this vision. Advancements will be necessary in detectors, optics, lasers, large deployable antennas, and low power, high-speed electronics. Future remote sensing instruments, more compact, economical and more capable by today's measures, with frequency-agility and multi-scene observation capability, will scarcely resemble their contemporary counterparts.

The resultant technologies necessary to achieve the science needs stated herein are summarized as follows:

- Telescope technologies for >5m^2 area
  - light-weight mirrors composition
    - glass/composite
    - thin film (stretch membrane/replicated shells)
  - Structures and latches
    - deploy/redeploy capability
    - elastic memory composite materials
  - Optical alignment techniques
    - active vs. passive
    - deformable/correction optics
- Common telescope requirements and testing
  - size, optical quality, wavelength range, orbit, operating temperature
- Space validation needs
  - nonlinear behavior in zero g environment

Partnerships between NASA and interagency, international, commercial and academic organizations will be essential to achieve this vision. The economic benefits will be shared across the globe.

VII. ACKNOWLEDGMENTS

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