1.0 INTRODUCTION:

1.1 Title of the Advanced technology:

Silicon Carbide Optics and Structure

1.2 ADT Lead:

TBR

1.3 Sponsoring IPDT:

Instrument Technologies and Architectures

1.4 Category of Proposed Use:

Category I

1.5 Supplying Organization:

SSG-Design and implementation MIT/LL-Integration

1.6 Primary Technology Contact: Christopher M. Stevens/JPL

1.7 Useful secondary Contacts:

Dexter Wang/SSG
Constantine Digenis MIT/LL
Don Lencioni MIT/LL

2.0 BACKGROUND:

2.1 Characterize the Advanced Technology

Silicon Carbide offers the advantage of very high stiffness to density ratio and very high conductivity to heat capacity ratio. These characteristics are superior to currently used materials for reflective optical systems. The high stiffness to density ratio allows mirrors of very low weight to be designed and still maintain the necessary surface figure to provide the performance required for high-resolution optical imaging. Lightweight optics lead to lightweight optical metering structures required to support them. This in turn leads to lighter instruments and therefore lighter payloads. Currently, only beryllium can compete with SiC for the lowest mass for a given optic size. SiC has the additional advantage of high thermal conductivity with relatively low thermal heat capacity. This property allows minimum thermal gradients for a given heat load. This is an advantage for an optical system on low Earth orbit that experience changes in thermal boundary conditions on regular basis. SiC performs without competition in this arena. This leads to an optimum optical system design of SiC optics with a SiC optical metering structure. Using the high stiffness to weight ratio, a very low weight optical system can be constructed.

2.2 How will the utilization of this technology enhance science in the 21st century?

The impact on 21st Century science will be profound. SiC optics and structures have the potential of lowering optical design systems weights an order of magnitude over current conventional systems. This lowering of weight means smaller and lighter payloads. This leads to the potential for more missions for a given funding level.

2.3 Why is this considered a revolutionary technology?

Silicon carbide has traditionally been used for refractory and abrasive purposes. It is a ceramic and has not been used for either optical or structural purposes. If we are able to exploit its desired properties, we must also overcome some deficiencies. These include extreme hardness, which leads to fabrication difficulties, and its brittleness, which leads to fabrication and survival difficulties. In addition, material and fabrication cost have the potential of staying the range of current, heavier optical systems. The appeal very lightweight optical systems costing the same as the conventional approaches are also revolutionary. The nature of the problems are extreme, but the payoff of the advantages makes this material revolutionary.

2.4 Why is space flight necessary to validate this technology?

Silicon carbide optics and structures have been fabricate and demonstrated repeatedly in the laboratory by SSG. The material is considered quite risky because of its brittleness. Operational missions have a very low tolerance for risk of this nature and have been unwilling to pioneer the use of silicon carbide. Without a NMP demonstration of this technology future use will be significantly delayed or eliminated.

3.0 PROPOSED IINTEGRATIOIN and VALIDATION APPROACH:

3.1 Describe the approach and justify your categorization the approach is simple.

We will fabricate and all silicon carbide optical system and demonstrate that it can support an Advanced LANDSAT imaging application in a flight program. The categorization as a "I" technology is obvious. The impact on the number and frequency of future science missions requiring optical systems is serious.

3.2 Describe the approach presently in budget

The SiC optical system and structure was fully funded in the EO-1 ALI budget through MIT/LL to SSG.

3.3 Describe how the approach affects the original, baseline pursued by the flight team

The approach is essentially the entire concept originally desired by the flight team. The only compromise was inclusion of the Grating Imaging Spectrometer as an aluminum subsystem rather than being based in SiC. This was done to minimize the cost of adding the GIS to the system.

3.4 Describe the interface with the spacecraft or ALI

The optical system and structure is the core of the ALI system. The optical system will interface to the focal planes with the WIS technologies, the GIS, the spacecraft and the thermal control enclosure. In addition, it will interface with calibration subsystems and a cover.

3.5 Describe the impact on the spacecraft or ALI

Since the optical system is the core of the ALI, its impact is severe. Weight, volume and interfaces to other subsystems will all be affected by changes to the optical system.

3.6 Describe the proposed integration and test of the technology

The optical system will be constructed at the engineering model level as a form and fit model and to validate the structural model. A flight model will be fully tested prior to delivery to MIT/LL for sensor level integration. Telescope level testing will include optical performance, shock and vibration testing at the flight acceptance levels, thermal vacuum for both survival and optical performance over the required operating temperature range.

3.7 Describe the approach for operations and to validation for the technology

The optical system is passive and has no major requirements on operations. The only significant impact on operations may be the duty cycle allowed to keep the telescope in operating temperature range. Current analyses do not indicate this to be an issue from optical performance point of view.

3.8 Describe the impact on spacecraft resources (mass, volume and thermal)

The ALI telescope mass and volume are defined in the instrument level ICD. Mass is targeted for 40 kilograms and the volume is HxWxD. No significant thermal constraints have been identified, however changes, to operation modes, orbit configurations and safe/hold modes need to be evaluated if changes are made from the baseline.

3.9 Describe how you plan to acquire the technology and identify the deliverables

Silicon Carbide optics involves a long series of fabrication steps. Material is purchased from a qualified supply vendor. The material is machined to near net shape by qualified vendors to SSG specified designs and processes. SSG then has a captive vendor coat surfaces reflecting with layer of silicon. This silicon is the diamond machined by qualified vendors. Finally SSG polishes and figures the elements to final surface figure and smoothness in its optical shop. Optical deliverables are the four reflecting elements of the optical design. These will be integrated into the optical bench. The optical bench will be fabricate from bulk material by a qualified vendor. SSG will then assemble the parts into an optical bench.

3.10 Describe any facilities issues of special GSE or FSE

SSG will develop "null test" cell to fabricate the M1 and the M2 mirrors. Other optics needs only standard tooling and test equipment.

4.0 AVAILABILITY:

4.1 Identify when an ETU would be deliverable to the flight team

A telescope ETU will be fabricated by SSG and delivered to MIT/LL by August? After evaluation by the MIT/LL the EDU will be available to the flight team. This is expected by?

4.2 Identify the earliest date when flight hardware would be deliverable to the flight team systems

SSG will deliver a flight ALI to MIT/LL by December 16, 1997. Focal plane integration will be performed at MIT/LL, as well as calibration and instrument buildup and qualification. It is anticipated to deliver the flight ALI to the spacecraft integrator by?

5.0 RISK:

5.1 Characterize technical risk and risk mitigation for the technology

Technical risk is driven by scheduled. Mirrors of t his classes have been fabricated by SSG in the past. Many of the fabrication steps have a "yield issue." Some parts are damaged in fabrication due to the brittle nature of the material. Risk mitigation is handled by having a series of elements in the fabrication s sequence. If a particular part has a problem, the next unit in the series is used. Experience is used to decide on the number of any particular part that will be made.

5.2 Characterize the schedule risk and risk mitigation and "trigger points" that represent decisions to shift to alternate development paths

Schedule risk is severe for this optical bench. Schedule risk is mitigated by alternate part utilization. A program defined "trigger point" has been defined at the Design Convergence Review (DCR). At this point an opportunity was created to select a baseline SiC optical structure or an alternate design path. Two alternate paths were identified. Due to schedule and technical performance risk, the alternate optical structure was selected at that point. The program decided to use Invar as the material for the optical bench. The use of Invar compromised the technology content of the EO-1 mission, but was felt to be necessary to mitigate some serious deficiencies in the fabrication path for SiC. This change was required to keep the project on schedule and on a budget. Invar has a similar coefficient of expansion as SiC and would no limit the thermal nature of the optical system. It has a significantly lower thermal conductivity, and will greatly reduce the susceptibility to thermal gradients, but not out the expected operating range of the EO-1 mission profile.

5.3 Characterize the budget risks and mitigation approaches

Sufficient spares and alternate substrates have been allocated in the program to accommodate the anticipated production risks. Although it is not possible to reduce the risk to zero, the only significant risk to the budget is if the schedule is stretched and the team needs to be funded beyond the nominal schedule. Four weeks of the schedule margin have been assumed for budgeting purposes

6.0 BUDGET:

Determine net cost incorporate the technology and validate it. SSG's information is limited to its contract amounts.

7.0 MANPOWER:

Characterize the team necessary to incorporate the technology into the EO-1flight

SSG has assembled a flight team to design and fabricate the ALI Telescope Subsystem. This team is working closely with the MIT/LL instrument team and the Swales Payload team as well. With the addition of the GSFC support, a strong and capable team has been assembled.

1.0 RECOMMENDED DISPOSITION:

Justify the incorporation of the technology into the EO-1 flight. The SiC optics is required for future space missions. Smaller, lighter and cheaper optical payloads are required for the concept of small space missions that the current NASA thinking requires. The SiC optical system must be validated in a NMP space demonstration to encourage other agencies to utilize the revolutionary advantages the material has to offer. Its high-risk perception has been a continued deterrent to its utilization on space missions and NMP is required to change this.