7.0 Critical Factors and External Assessment Introduction

Successful execution of the SEC roadmap depends upon several factors beyond the control of the Division. Major factors are: access to space, collaboration within NASA and with other organizations, and infrastructure issues.

7.1 Access to Space

7.1.1 Launch cost and availability

All SEC missions require uninhibited access to space. Launch costs for Solar Terrestrial Probe missions currently comprise approximately one fourth of the total mission cost. Reductions in launch costs would enhance science returns by shifting money currently spent on launch vehicles into enhanced spacecraft and scientific instrument capabilities. Continued availability of launch vehicles for small payloads is being questioned. There are several ways to reduce launch costs and increase launch vehicle availability.

Direct procurement of US launch services

NASA should negotiate directly with launch providers to obtain, for example, complete packages of spacecraft, integration, and launch services at reduced rates for individual missions.

Additional launch vehicles

NASA should broaden the range of launch vehicles to fill gaps in capability. For example, they should encourage a range of intermediate launch capabilities between the small and large launchers already available. This would increase competition for launch capabilities, provide a variety of launch options, and allow launch capabilities to be tailored to particular missions.

Foreign launch vehicles

NASA should pursue the option of selecting foreign launchers for certain missions. This opens up the possibility of additional competition, thereby reducing launch costs for both foreign and domestic launchers.

Secondary payloads

NASA should develop the ability to purchase secondary payload space on US and foreign launch vehicles, in some cases for entire missions and in others to enhance mission capabilities. A dedicated secondary payload program increases access to space, reduces overall mission costs, and provides the opportunity to perform test bed-like development projects with greatly reduced launch costs.

7.1.2 Importance of the Explorer, Discovery, Sub-Orbital, and Testbed Programs to SEC

The explorer, discovery, and sub-orbital programs fill a critical niche in SEC science. They perform specific, focused scientific investigations on SEC themes using the latest technology, accepting a greater degree of risk than SEC missions like the Solar Terrestrial Probes or Living With a Star. This enhanced risk often results in a higher science to mission cost ratio. Furthermore, the specific, focused science investigation of these missions reduces the time for mission development. As a result, the Explorer and Sub-Orbital programs greatly enhance the SEC Division’s overall science return. Adding a Space Testbed program to these programs would permit the development of spacecraft subsystems and reduce overall mission costs. Finally, the shorter schedules of all these focused programs encourage the training of young scientists and engineers who will become essential personnel on future SEC missions.

Explorer Program

NASA should strive to maintain the Explorer program originally conceived by alternately selecting small and medium SEC-theme Explorer missions each year. Similarly, it should launch either a medium or a small explorer mission each year.

Discovery Program

NASA’s Discovery program provides the planetary community with access to relatively low cost missions. While these missions focus upon planetary themes, NASA and the planetary community should remain open to including Discovery missions that address comparative planetary environments. In the past, this approach has resulted in greatly enhanced scientific return.

Sub-orbital Program

The NASA Sub-orbital Program has produced outstanding science throughout its lifetime. Many phenomena have been discovered using rockets, rockoons and balloons and many outstanding problems brought to closure, particularly when teamed with ground-based facilities. Unique altitude ranges and very specific geophysical conditions are often only accessible to sounding rockets and balloons, particularly in the campaign mode. Furthermore, the extremely short sounding rocket schedule provides an excellent training ground for young scientists and engineers, including the opportunity for a student to be in a project from cradle to thesis. This short schedule also allows for significantly higher risks, with correspondingly greater scientific returns. NASA should strive to maintain and enhance the funding of the sounding rocket program and continue to develop cost savings measures that place additional responsibility and resources in the hands of the sounding rocket PI institutions.

Space Testbeds

The SEC's strategic plan increasingly emphasizes missions that employ fleets of satellites to provide multi-point diagnostics of the Solar-Terrestrial interaction. If the standard percentage scheme for development margin is used for all the satellites, the resulting costs will be prohibitive. SEC needs a flight test program to lower the programmatic risks for these missions and to allow a quick, high-risk test of the first prototype spacecraft or at least the key sub-systems of such spacecraft. Some of these functions are accommodated in the sub-orbital program (limited in flight duration, but critically important), and also the Space Technology series (e.g., ST-5). However, higher profile programs that do not have a specific technology focus tend to receive higher public attention, particularly when the program "fails". As a result, costs continue to increase for programs providing rapid access to space. NASA should consider teaming with other US Government agencies, in particular the Air Force Space Test Program, to implement a quick, low-cost orbital program enabling rapid access to space to test missions and mission concepts in a low-profile environment.

The LWS Space Environment Testbeds, described in Section 4.5, Technology Implementation Plan, provides a step in this direction by utilizing teaming opportunities with interagency and international partners. The flight testing provided by these low profile Space Environment Testbeds will enable the infusion of new technology thereby reducing both risk and excessive design margins for future space missions.

7.1.3 Large Missions

The SEC mission roadmap contains some missions that are outside of the typical funding limitations of Solar Terrestrial Probes and Living With a Star mission cost caps. One of these missions is Solar Probe, which is a very high priority mission that accomplishes SEC science that is not possible with any other mission. For this mission and some others, NASA needs to be flexible in determining overall mission cost caps. For its part, the SEC community must realize most missions must stay within particular mission cost cap requirements or future missions will be impacted.

7.2 Collaborations Within NASA and With Other Organizations

7.2.1 Vital Need for L1 Observations

All SEC missions benefit greatly from solar wind particle and field measurements at the L1 libration point. Given the budget limitations for SEC missions, the STP and LWS mission lines assume that L1 monitoring will continue. ACE, WIND, and SOHO currently fulfill most needs of the observational and modeling communities for L1 monitoring. The capabilities of these spacecraft could be greatly extended at low-cost by launching TRIANA. (The primary science objective of this mission is in the Earth Sciences directorate; however, it does carry solar wind monitoring instruments). The measurements of these four spacecraft could be used to calculate vector particle and field gradients, as well as the internal structure, of large- and small-scale heliospheric disturbances aimed towards the Earth's magnetic shield. Since the SEC has no plans for subsequent missions to make these critical measurements, NASA should work closely with other government agencies to develop low-cost "operational" L1 missions that provide real-time solar wind data for space weather forecasts (e.g., those provided by the NOAA Space Environment Center) in addition to data for scientific study of the solar wind and its effects.

7.2.2 Intra-agency Collaboration – heliospheric observations on planetary missions

Historically, the major advances in both heliospheric physics and comparative magnetospheres resulted from collaboration between the Sun-Earth Connection and Solar System Exploration. In fact, there have only been three stand-alone heliospheric missions: Helios (a German mission), Ulysses (joint US and ESA mission), and ACE (a US Explorer mission). The remaining heliospheric missions and all of our comparative magnetospheric missions have resulted from the inclusion of space physics instrumentation on planetary missions such as Mariner, Pioneer, Voyager, Galileo, and Cassini. The payoff of these complementary payloads has not been just one-way. For example, Voyager's discovery of volcanic activity on Io and the Io plasma torus showed the importance of understanding Jupiter as a system, including the planet, its moons, and magnetosphere. With the revolution of 'faster-better-cheaper' missions, the planetary missions have become smaller and more focused. NASA needs to continue to encourage the Solar System Exploration and Sun-Earth Connection themes to collaborate on new planetary and SEC missions.

7.2.3 Inter-agency Collaboration – DOD, NOAA, NSF, etc.

The goals of the SEC's Living With a Star program necessitate close collaboration with other agencies such as the DoD and NOAA. For example, the LWS program assumes that there will be hard and soft X-ray monitors (on GOES spacecraft and its successors) to supply data essential to the Earth-atmospheric aeronomy and climate studies. In return the LWS and Solar Terrestrial Probe missions provide important data for other agencies. For example, the real-time ACE and IMAGE data provided to the NOAA Space Environment Center have revolutionized space weather forecasting. NASA should initiate and maintain close collaboration with other government agencies to maximize scientific return from its missions and maximize the government and private sector return on its space investments. This collaboration becomes increasingly important as the LWS program begins to make significant progress on the physics behind those aspects of space variability that affect society.

7.2.4 Ground-based observations

Historically, SEC missions have benefited significantly from coordination with ground-based observations, typically under the auspices of the National Science Foundation. Ground-based radars, all-sky imagers, riometers, and magnetometer chains provide the global context of the ionosphere and upper atmosphere for magnetospheric and ITM missions. Many missions require ground-based coordination to complete their science objectives. NASA should initiate and maintain close collaboration with NSF and other agencies that design, develop, and implement ground-based observing systems.

7.2.5 International Collaboration on Missions

SEC missions receive significant scientific leverage from international partners. This participation depends on continued NASA and US policies supporting scientific cooperation. NASA should initiate and maintain close collaboration with other space agencies. The most significant policy that affects this international participation is the International Traffic in Arms Regulations (ITAR)

7.2.6 International Traffic in Arms Regulations (ITAR)

ITAR places significant burdens on scientists and program managers engaged in SEC science investigations that are international in scope. The regulations cast a wide net, affecting virtually all space flight hardware. Compliance levies additional burdens and stresses on program managers and scientists who must prepare applications for Technical Assistance Agreements (TAA). The regulations can become self-defeating in certain cases. For example, foreign collaborators can be barred from operation centers (regardless of existing TAAs), making them unavailable for important and sometimes critical decision processes. In other cases, the TAA may not be approved until after the Phase A period of the project, effectively preventing team meetings from being held during that important formative period of the mission life cycle.

NASA can take constructive steps in the ITAR arena to facilitate efficient mission planning and execution. For example, NASA could adopt a more proactive role and brief the State Department regarding a particular mission early in the project life cycle (i.e., during pre-Phase A studies). This could result in the granting of a blanket approval for appropriate activities associated with individual missions or, at a minimum, an expedited approval procedure. Short of that, NASA may be able to negotiate with the State Department to obtain TAA approvals during the proposal evaluation phase, thereby enabling teams with international components to commence team level meetings and planning during Phase A.

7.3 Infrastructure Issues

7.3.1 Spacecraft Communications - DSN

Although much SEC science is done near the Earth, significant science in this roadmap requires spacecraft in solar orbits far from Earth or orbits about other planets. Furthermore, some of these missions require large downlink telemetry rates. This represents a departure from traditional SEC missions whose tracking requirements could be met by small ground stations. The new suite of missions will require the state-of-the-art capabilities of an already fully subscribed Deep Space Network. To realize the potential gains from these new missions, it is necessary for NASA to continue to upgrade and expand the capabilities of the DSN to be able to track more spacecraft and with larger telemetry bandwidths.

7.3.2 Information Technology

The information technology infrastructure has enabled broad access to NASA databases. It addresses the problem of how to compare data from different sources, at different locations, and on different computer systems. Most NASA scientific data is in the public domain and maintaining the reliable and user-friendly information technology infrastructure has made this a reality rather than an ideal. In the future, far greater demands will be placed on this infrastructure by the large volumes of data produced many of the SEC missions. NASA should continue to maintain and incorporate developing technology into this infrastructure to meet these mission needs.

7.3.3 Human Resources – Need for Scientists and Engineers

The 25-year roadmap plan assumes that adequately trained scientists and engineers will be available to carry out the missions. This assumption depends on the existence of clear paths by which technically trained people can join NASA projects. Paths currently exist, for example, through special training programs, college and university investigator opportunities, and private industry. NASA should continue to support and enhance current paths and explore new training paths. Enhanced development of joint NASA-University collaborations is one of many examples of ways NASA can strengthen engineering and scientific participation in NASA programs.

7.3.4 Supporting Research and Technology (SR&T) program

The Supporting Research and Technology (SR&T) program has been of immense value to the mission of the Sun-Earth Connection Theme. The Sun-Earth Connection requires a mechanism to support innovation in both research and technology development. Furthermore, the value of present and past research missions benefit greatly from research not directly tied to a mission or mission line, but from one that permits integration of research across mission lines and data sources. Finally, developing SR&T proposals helps young scientists career development. NASA should maintain a healthy SR&T program and continue to provide easy access to mission data for these types of studies.