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Ra:

The Sun for Science and Humanity

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Abstract

At the 1996 Summer Session of the International Space University, held in Vienna, 53 space professionals from 18 countries addressed the world's future programme of solar-terrestrial exploration and applications. Their mandate was, through an international perspective, to explore and document strategies which will increase our understanding of the Sun and its effects and help us apply solar knowledge for the benefit of mankind.

The changed global political, economic and technological environment within which space activities take place has created both obstacles and opportunities for solar exploration and applications. The economic risks of insufficient knowledge of solar phenomena are greater now than ever before, for both terrestrial technologies and space-based systems. The blurring of the line between basic and applied sciences and the movement towards interdisciplinary science missions has created a favourable climate for joint science and applications endeavours. The Ra report is a call to action. It presents an international Strategic Framework, containing programmes for the Near-, Mid- and Far-Term. It integrates solar science and applications, capitalises on global resources and talents and harmonises with the political and economic environment. We recommend the immediate establishment of a Working Group for International Solar Exploration and Applications. This would ensure the implementation of a Strategic Framework, synchronise efforts in different countries, facilitate the interaction between science and applications and help combine the output into products useful on a global scale.

The Ra Project Team

The ISU was founded in 1987 as a non-profit, non-governmental institution. It was created with the objective of becoming the world's leading centre for educating and training tomorrow's space professionals. The ISU Summer Session Program brings together international space experts from academia, industry, and government to educate students in multidisciplinary and advanced issues in space development in a ten week format. The design projects carried out by the students during the session have two purposes: first, to provide learning in international teamwork on problems requiring a multidisciplinary and multicultural approach, and second, to yield published results that can be influential in the world-wide space community.

The Ra Project Team at the Technical University of Vienna in September 1996, ten weeks after the start of the project.

Introduction (1)

The economic risks of insufficient global knowledge concerning dangerous solar phenomena have never been higher. The ever-increasing amount and level of complexity of the global space infrastructure, used by both developed and developing nations, points to an immediate need for improved solar warning and forecasting capabilities. The political environment recognises these economic needs, resulting in an enhanced opportunity for developments in solar warning and forecasting.

There has been an international trend towards greying the line between the basic and applied sciences. This trend has the potential to enhance the cohesion of the scientific community by diminishing traditional rivalries between speciality disciplines. The convergence is also notable for the movement towards interdisciplinary science missions, and the current climate is favourable toward joint science and applications endeavours.

The future of solar exploration and applications will be determined largely by how well the relatively low budgetary priority of solar and heliospheric physics and solar warning and forecasting services is overcome. The combination of diminishing national space budgets, increased opportunities for co-operation, and growing technological capabilities has led to a sustainable emphasis on smaller, modular, networked spacecraft with prioritised objectives. Disciplinary cohesion, inter-agency co-ordination, international co-operation, applications rationales, and smallsat technology offer a combination of effective organisational means to sustain and even increase solar exploration and applications efforts.

Introduction (2)

The Ra report, obtainable from the ISU addresses at the end of the poster, represents the efforts of the Ra team over ten weeks, working to the following mission statement:

Through an international perspective, we will explore and document strategies which will increase our understanding of the Sun and its effects, and help us apply solar knowledge for the benefit of humankind.

This poster presents the core ideas of the Ra report, namely:

- The Ra Strategic Framework- an international programme for solar exploration and applications.
- The Sauna mission- a science and technology demonstration mission for the medium term.
- The Working Group for International Solar Exploration and Applications- a body for co-ordination and planning.

Objectives

To guide the development of the Ra Strategic Framework, we defined scientific and applications objectives.

- The primary scientific objectives are:
  - To understand the physical processes leading the Sun to emit plasma structures and high energy particles that are potential threats to humans and technology.
  - To understand the physical processes which my lead the Sun to influence our climate.
- From an applications perspective, we adopted three broad objectives:
  - Identify and exploit application spin-offs from science missions and other sources of data.
  - Identify possible solar-terrestrial missions dedicated to a particular application.
  - Identify future applications that require technology development.
  - Our principal applications focus was to improve solar threat monitoring and early warning systems.

We stress the importance of stereoscopic imaging, as well as observations at high spatial, spectral, and temporal resolutions, and of long duration measurement. To study the corona we need measurements from multiple observing locations and orbits closer to the Sun. Further, the physics of the Sun's interior should be emphasised particularly in the Mid- and Far-Term programmes. Emphasis should be placed on monitoring space weather and forecasting Sun/Earth interaction.

A Strategic Framework for Solar Science and Applications (1)

Near Term (1997-2000)

- Apart from tapping into current programmes and capabilities- as for example the sharing of science data- we propose to improve management and co-operative structures by the creation of a **Working Group for International Solar Exploration and Application** (**WG ISEA**) that would co-ordinate and plan the many solar missions that individual nations have proposed.

Mid-Term (2001-2010)

- Here we propose more ambitious programmes, that require technology development. In particular, to fulfil the high priority science objective of understanding the corona, we envision a stereoscopic solar imaging system (Sauna), that would also support the currently scheduled combined Russian-US FIRE mission (SoHO may have expired). By building on the technology demonstrated by Sauna, we propose to begin developing a continuously operating solar threat monitoring and early warning system, marking the beginning of a solar applications system.

- **Far-Term (2011-2020+)**

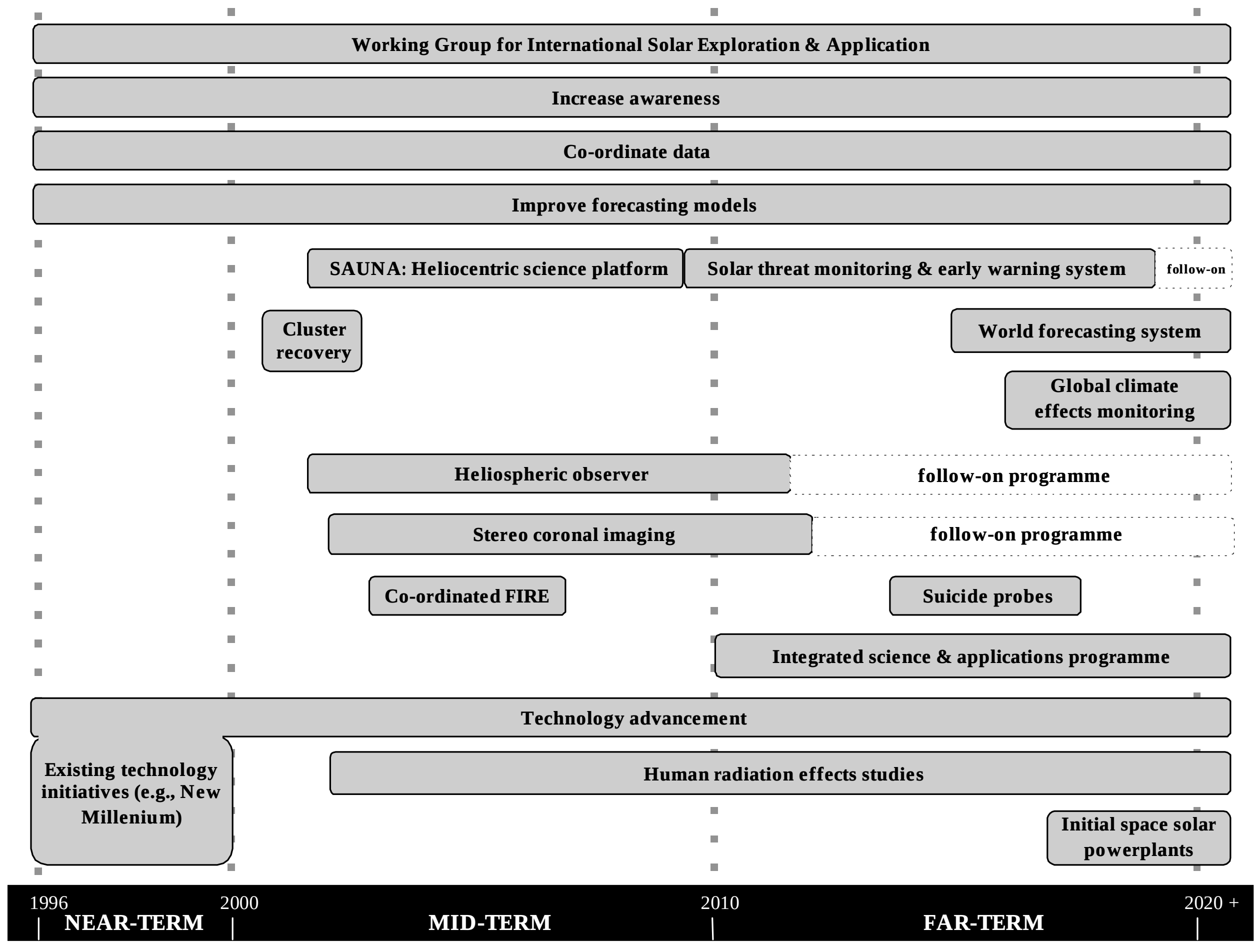
- For this period we envisage an integrated advanced technology programme for space science and applications that builds on the foundations created earlier and may have combined platforms or share common resources. The solar threat and early warning system should have matured to a forecasting system providing global benefits and- together with the integrated data of old and new long term missions- giving clues to the relationship of the Sun to the Earth's climate. Furthermore we propose to focus on other applications such as space solar power plants.

A Strategic Framework for solar science and applications (2)

We believe the Ra Strategic Framework is significant because it

- is a coherent plan over time,
- relies on existing and planned programmes, and benefits from them,
- considers the political and economic environment, including future trends, and seeks to shape that environment for the benefit of solar science and applications,
- integrates solar science and applications, showing how one can benefit the other,
- is an international framework that capitalises on global talents and resources,
- seeks to provide global benefits.

Timeline for Strategic Framework



Near-Term (1997-2000)

Programme	Objectives	Description	Rationale
Cluster recovery	Complement to SoHO and ground-based observations	A replacement for the Cluster spacecraft lost in June 1996	Utilise all the existing work done for the original Cluster towards what Ra team believes to be the most pressing concerns
Improve forecasting models	Improve space environment forecasting	Perform correlation studies; innovative acquisition of new forecasting models	Current operational forecasting models are old and empirical; better models will save degradation and replacement cost
Co-ordinate science and other data	Make use of all past and current data	Continue ground-based observations; create an international data centre; research with and co-ordinate science data; co-ordinate future planning of independent groups	Other research communities may be interested in solar data, easier data access provides more time for actual research
Working Group for International Solar Exploration and Applications (WG ISEA)	An international forum for the planning, co-ordination, and implementation of an international effort in solar exploration and applications	Incorporates science and applications interests from government and private sectors; submits to government agencies specific recommendations for actions necessary for fulfilment of a solar exploration and applications strategic plan, while encouraging independent complementary efforts	Changing global paradigm for space science and applications points to the advisability of combining resources across national boundaries and between science and applications disciplines. We believe WG ISEA is the most efficient and expedient organisational forum to enable this merger
Increase awareness of solar science and Sun-Earth interaction	Increase awareness among: general public, space community, power companies	Develop a "common language" for solar science and applications; work with planetariums and museums; educators via WWW; correlation study on satellite anomalies, ground power station anomalies and solar activity	Maintaining funding will require a basic public understanding; science, as a "public good", should be shared; establishing a correlation between space weather and satellite anomalies will motivate further investigation/ interest
Actively incorporate existing technology initiatives	Continue with efficient technology development	Examples include: Japan Nereus, ESA TRP (esp. Theme 10) and GSTP, NASA New Millennium, University Small Sat, Clementine, DC-XA, Commercial bus	Matches post Cold War era trends; logical progression into the future

Mid-Term (2001-2010)

Programme	Objectives	Description	Rationale
Sauna: a heliocentric, near-Sun science platform	High resolution coronal and surface imaging; *in situ* solar wind measurements; technology demonstrator	Ion-propelled single spacecraft to 0.2 AU heliocentric orbit. 5 yr. mission duration	Affordable ($200M) science mission and demonstrator of survivability near Sun; precursor to heliocentric constellations
Solar threat monitoring and early warning system	Measure position, velocity of southward interplanetary magnetic fields	Heliocentric orbiters; Other options included: L4/L5 tripwire and solar wind event imaging and tracking	Initial dedicated space environment system; selected option most compliant with identified potential customers
Stereoscopic coronal imaging system	Magneto-hydrodynamics of corona	Small remote sensing platforms at L1, L4 and L5	First stereoscopic mission- low cost but high return- opening the third dimension
New heliospheric observing platform	Helioseismology, solar atmospheric and coronal studies, solar wind monitoring	Extended SoHO mission, then smaller follow-on	Maintenance of long-term observation and monitoring
Co-ordinated FIRE Mission: Russian Plamya & U.S. Solar Probe	Heating of the corona and acceleration of solar wind	Dual spacecraft close flyby mission to 4 R_s and 10 R_s	Low-cost close flyby mission with finely targeted objectives
Human radiation studies on host spacecraft	Determine radiation risks for humans in interplanetary space and requirements for protection	Tissue-equivalent dosimeter measuring direct radiation and secondary radiation from shielding	Essential precursor for human Mars exploration or lunar base; could be a show-stopper

Far-term (2011-2020+)

Programme	Objectives	Description	Rationale
Integrated solar science and applications programme	Reduce costs by co-operation in areas of common interest and by exploiting free opportunities	Options: science "piggybacking" on applications; application prototype sensors on science platforms; use of common buses	Solar science and applications have common elements; an integrated programme spreads risk and provides synergistic benefits
Small suicide probes	Explore acceleration and heating of corona by direct sensing	Wide range of concepts available	Understanding of coronal physics is of high scientific value
Worldwide space environment forecasting system	Enhance the benefits of space environment forecasting for humankind	Characteristics include: distributed, provides information to developing nations, integrates military, civil, commercial data; independently maintained in participating nations	Political, social and commercial interests ultimately converge in the maximum availability of early warning systems
Preliminary space solar power applications	Explore ways to solve the imminent global energy crisis	Prototype space-based solar power station for small-scale distributed use	Solar power represents a "next generation" application
Monitoring the Sun's effect on Earth's climate	Understand the impact of variations in the solar output on the Earth's climate	Long-term space-based observation programme to monitor solar output and Earth's climate	Co-ordinated programme allows long-term data to be gathered so that potential correlations can be uncovered

The Sauna Mission

The Sauna mission will perform solar science in a low solar orbit over a time span of several years. It can thereby serve as a demonstrator for the constellation of spacecraft to monitor the solar environment in this region (Far Term). We have endeavoured to make this mission politically acceptable by designing to a US$200m Life Cycle Cost and by applying no controversial technologies such as Radioisotope Thermoelectric Generators.

Mission Objectives:

To perform science investigations of the Sun and its environment in a circular heliocentric orbit at 0.2 AU and demonstrate long-term spacecraft survivability in a near solar orbit (see diagram opposite).

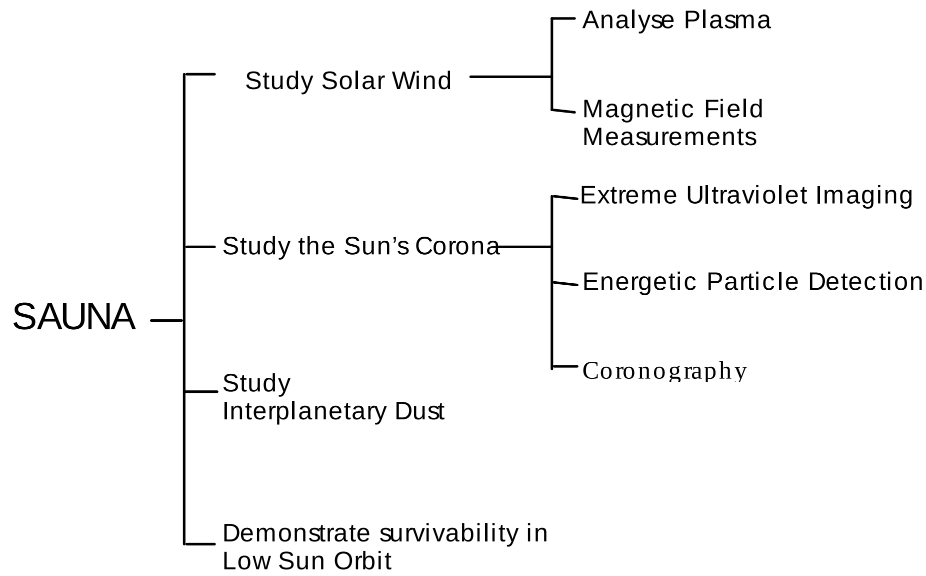
Spacecraft Configuration:

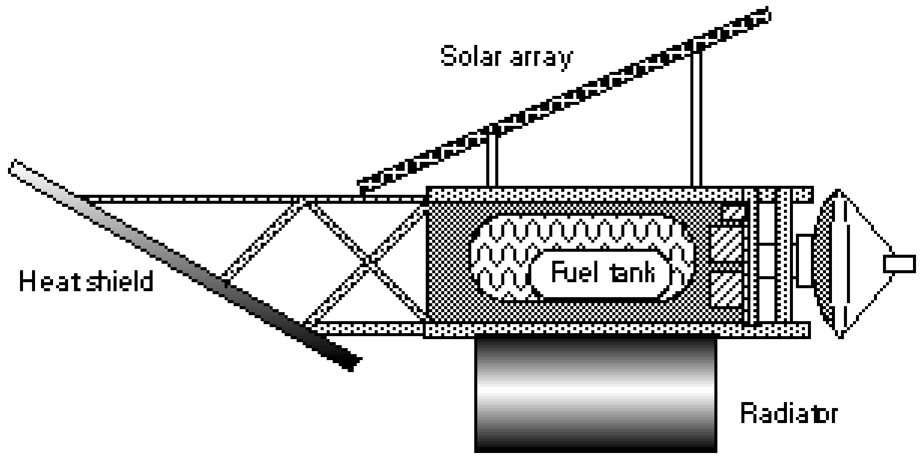
The spacecraft will use advanced ion propulsion systems which require a large amount of power, hence the need for large solar arrays. A heat shield is needed to maintain the spacecraft at operating temperature.

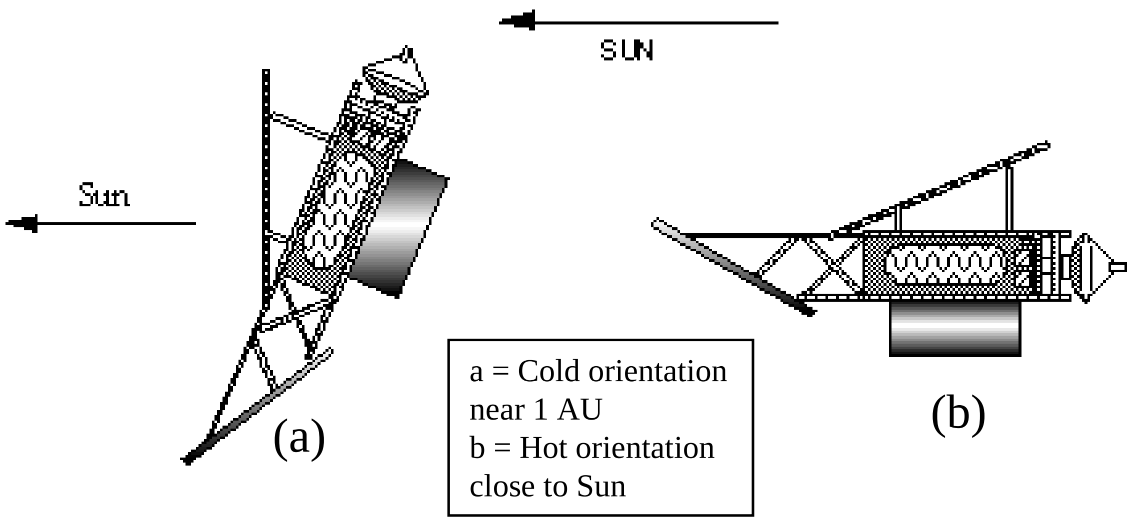
Programme Timeline:

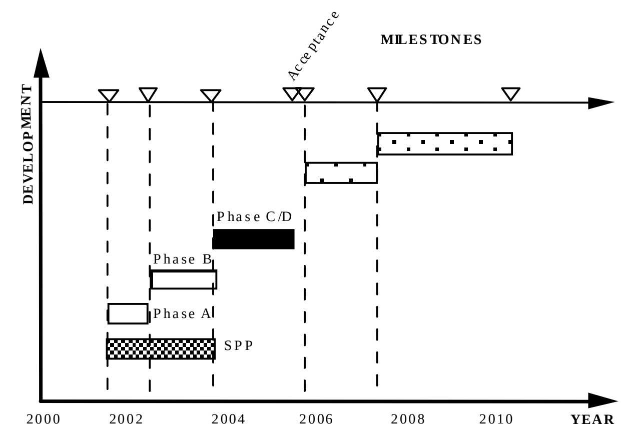
The SAUNA mission can be launched as early as 2005, depending on the availability of a qualified 0.2N ion thruster or equivalent technology. The significant elements of this programme plan are a total design and development time of 4 years and a total programme time of 9 years plus an optional mission extension.

The spacecraft and programme timeline are shown on the next page.




Solar array
Heat shield
Fuel tank
Radiator


SUN
Sun
(a)
(b)
a = Cold orientation near 1 AU
b = Hot orientation close to Sun


Acceptance
MILESTONES
DEVELOPMENT
Phase C/D
Phase B
Phase A
SPP
2000
2002
2004
2006
2008
2010
YEAR

A Working Group for International Solar Exploration and Applications

To integrate basic and applied scientific objectives, a forum for solar exploration and applications co-ordination and planning is suggested. This forum- the Working Group for International Solar Exploration and Applications (WG ISEA)- should be formed before the Summer 1997 NASA Woods Hole Sun-Earth Connections Roadmap meeting.

The means by which the WG ISEA achieves its international collaborative objectives should be flexible. It should include a Mission Co-ordination Group to synthesise co-ordination and data sharing between national solar science and applications missions outside, with, and beyond the International Solar Terrestrial Physics programme. To supplement inevitable gaps in solar observing capabilities, the WG ISEA should also form a Mission Planning Group to recommend a strategic framework for solar exploration and applications that takes advantage of existing, cheap platforms, for quick response solar observation or technology demonstration.

National hardware contributions to international efforts optimise the political environment for space activities. The use of standardised, common spacecraft systems, however, is also a key to reducing the cost of solar system exploration. To take advantage of this economic opportunity while realising its political realities, the WG ISEA should include an engineering group for the design of solar spacecraft reference models. This group provides a first step towards realising the benefits of international co-operation in space exploration beyond the co-ordination of scientific data acquisition and data dissemination.

Increased understanding of solar and heliospheric physics will improve solar forecasting models, and current national plans to consolidate agency level solar warning and forecasting resources will incorporate these advances. Existing international solar warning and forecast data distribution networks like the International Space Environment Service will feed data into these forecasts, but the advances needed to make solar warnings and forecasts relevant to potential users will require capital investment in hardware. National solar warning and forecasting plans should look abroad for opportunities to co-ordinate the deployment of dedicated but nationally discrete solar warning spacecraft. Meeting user needs will provide horizontally integrated commercial opportunities within the larger government space warning and forecast services.

Acknowledgements

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Further Information

Ra: The Sun for Science and Humanity, Design Project Executive Summary, International Space University, 1996.

Ra: The Sun for Science and Humanity, Design Project Report, International Space University, 1996.

(Copies of the Design Project Executive Summary or the Full Report may be ordered through the ISU Headquarters in Strasbourg or the ISU North American Office).

ISU Web site: http://www.isunet.edu/

Ra Project Web pages: http://www.isunet.edu/Academic/SSP/isu96/RA.html

Sun-Earth Connection Roadmap: http://espsun.space.swri.edu/~roadmap/

NASA Space Physics Sun-Earth Connections Home Page: http://umbra.nascom.nasa.gov/spd/

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