Australian Space Research Institute Ltd

ALUMINATE Project

Project Proposal

Pre-Phase 0 – Provisional Approval

ASRI-ALUM-M-PPR-ver0E.doc

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AMENDMENT LOG

Ver.	Release Date	Description of Change (Including Sections Affected)	Author	Reviewer / Approver
0A	2001-04-11	Draft template raised and sent to ALUMINATE-EXEC e-mail list for review.	Cameron Boyd	Project Executive
0B	2001-05-07	Changed minor formatting; updated based on comments; sent to ALUMINATE-EXEC list for final review.	Cameron Boyd	Project Executive
0C	2001-05-22	Revised various sections, esp MDR date and risk management. Now allows two-step MDR.	Shaun Wilson	Project Executive
0D	2001-06-03	Tidied document, enhanced risk assessment, clarified terms in tables, filled target/mission table.	Cameron Boyd	Project Executive
0E	2001-06-09	General review and corrections prior to initial submission to ASRI Board for provisional approval	Shaun Wilson	Shaun Wilson

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EXECUTIVE SUMMARY

This Project Proposal for the ALUMINATE Project outlines a brief overview of the proposed project to design a modular multi-mission spacecraft from COTS components for various extra-earth orbital missions scenarios. Preliminary analysis includes the following target classes:

- Mars or Venus
- Moon or Near Earth Object (NEO)

The set of potential mission scenarios under investigation includes:

- Communications Relay
- Remote Sensing
- Remote Delivery

Costs will be minimised through the use of recognised international best practices and standards in space engineering and the utilisation of student coursework and voluntary industry professionals.

Using the distributed and low-cost design approach pioneered by ASRI, the ALUMINATE Project builds on the skills and experience gained from the JAESAT Project while providing a unique Australian space project.

1 DOCUMENT OVERVIEW

1.1 PURPOSE

The purpose of this Project Proposal is to propose that ASRI re-approve the ALUMINATE Project based on the ASRI Project System in accordance with the approval process shown in Figure 1.

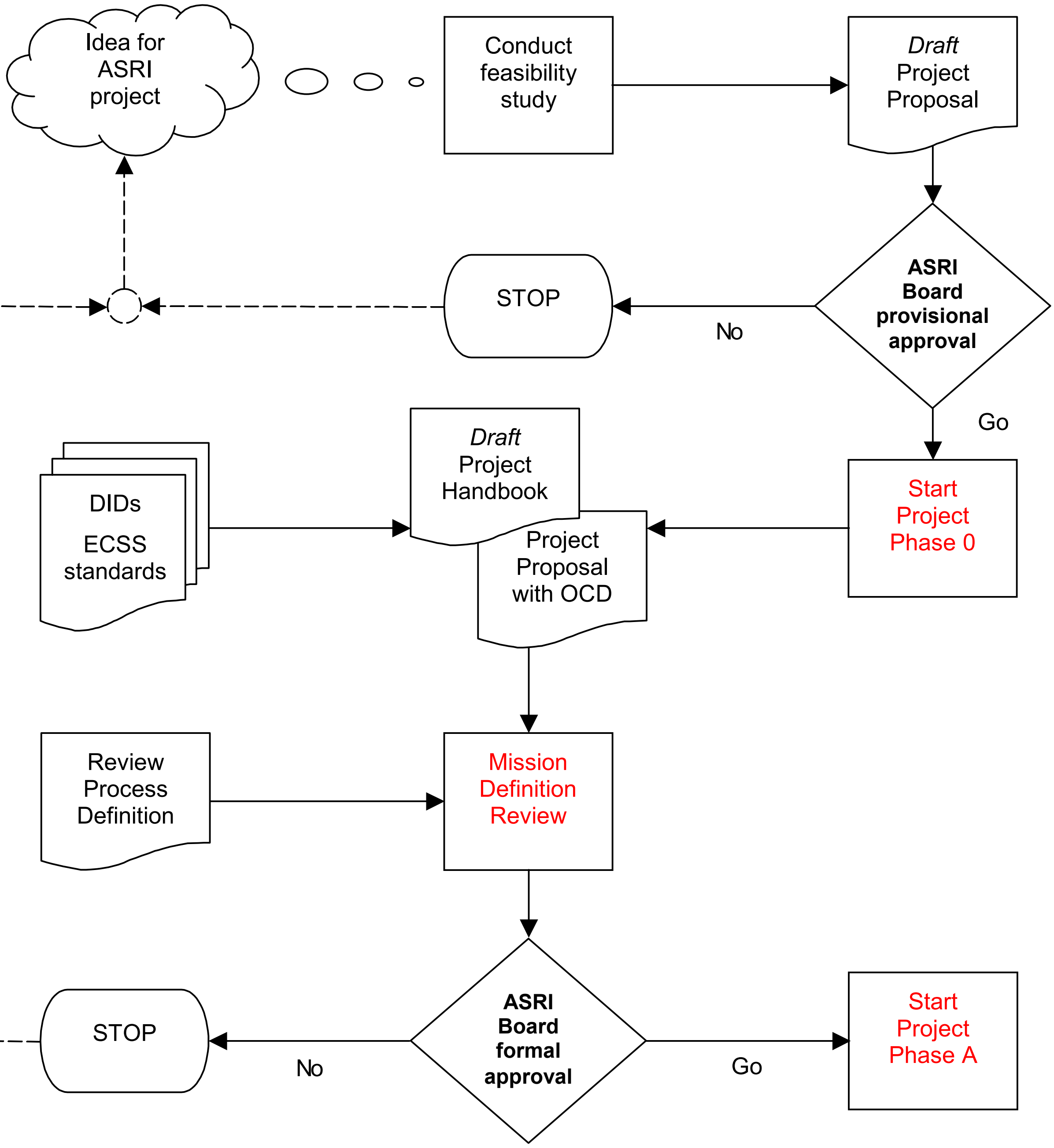

Figure 1. ASRI project approval process

1.2 FORMATTING AND IDENTIFICATION

To ensure uniformity of appearance, ASRI project documents are formatted with the styles defined in the applicable template or DID.

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1.3 HANDLING AND CONTROL

Unless assigned a CONTROLLED distribution control, ALUMINATE Project documents are stored in the ALUMINATE Project Virtual Project Office (VPO) at www.asri.org.au. Hardcopies are not amendment controlled and thus should not be used for normative reference.

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1.4 SOURCE DID

This Project Proposal for the ALUMINATE Project was created from the formatted Project Proposal Data Item Description (DID) available at www.asri.org.au.

The Project Proposal DID was created by ASRI from a 'running sheet' supplied by Nigel Davies. The 'running sheet' is used in commercial practice to staff new ideas through an organisation and to ensure that all relevant issues have been considered prior to approval or rejection. This 'running sheet' concept has been tailored for ASRI projects.

1.5 STRUCTURE

This Project Proposal is structured to encourage a full description and analysis of a proposed project as follows:

Document overview	Self-explanatory.
Proposal description	Outlines what the project will aim to achieve, how, with what resources, and in what time frame.
Proposal analysis	Considers the assumptions underpinning the proposal, the consequences of adverse outcomes in those assumptions, options available to the project at various stages, risk assessments, risk mitigation proposals and risk monitoring strategy.
Progress & Assessment	Records of the consideration and authorisation of the progress of the proposal through the ASRI project authorisation process.
Appendix – GMSP Concept Description	Provides a summary of preliminary technical research undertaken, directions of approach, and areas of priority for future research.

1.6 DEFINITIONS

1.6.1 Internal Definitions

Terms and abbreviations used in this document are defined below:

ALUMINATE	Australian Lunar-Mars Investigation and Technical Evaluation
AU	Astronomical Units
CCSDS	Consultative Committee for Space Data Systems (CCSDS) (see www.ccsds.org)
COTS	Commercial-Off-The-Shelf – a product available 'as is' via commercial means without the need for any development by ASRI, although development of interfaces for the purpose of integration may be required.
DID	Data Item Description
DRL	Data Requirements List
ECSS	European Cooperation for Space Standardisation (see www.estec.esa.nl/ecss)
GMSP	Generic Modular Spacecraft Platform
ISO	International Standards Organisation (see www.iso.ch)

MEF	Mission Enabling Factors
ODBH	On-Board Data Handling
PA	Product Assurance (superset of Quality Assurance)
PM	Project Management
Program	An enduring management structure encompassing an ongoing series of time-limited activities, usually projects, conducted around a common theme, such as launch vehicles or satellites. ASRI has four programs: • Hypersonics Program • AUSROC Launch Vehicle Program • Satellite Program • Small Sounding Rocket Program
Project	A time-limited activity with a defined purpose, such as building and launching a microsatellite.
SE	Systems Engineering (*Note:* The ECSS uses the (singular) term 'System Engineering')
SEP	Solar Electric Propulsion
UQ	University of Queensland
VPO	Virtual Project Office – a sub-domain of the ASRI web site at to www.asri.org.au where project documentation is stored.

1.6.2 External Definitions

Further definitions are contained in higher-level project documents (if any), the *ASRI Glossary of Terms* and the *ECSS Glossary of Terms*.

1.6.3 Precedence of Definitions

Should there be a conflict in definitions, the following order of precedence applies:

- Section 1.6.1 of this document
- Higher-level ALUMINATE Project documents

- *ASRI Glossary of Terms*
- *ECSS Glossary of Terms*

1.7 References

The documents listed below become part of this Project Proposal to the extent referenced herein:

- *ASRI ECSS Tailoring Schedule*
- *ASRI Glossary of Terms*
- ASRI-ALUM-E-MSS – *Mission Scenario Specification*
- ASRI-ALUM-E-PTS – *Preliminary Target Study*
- ASRI-ALUM-M-SRD – *Stakeholder Requirements Document*
- ECSS-P-001A – *ECSS Glossary of Terms*
- Fischer, H., Rabenau, E, September 1995, "Analysis and Evaluation of Operational Concepts for Spacecraft with Special Focus on Small Satellites and Low-Cost Options", *Proceedings, 1st International Symposium on 'Reducing the Cost of Spacecraft Ground Systems and Operations'* (www.satops.de/PAPRAL9.htm)
- Fortescue, P., Stark, J. (eds), 1995, *Spacecraft Systems Engineering*, 2nd Edition, John Wiley & Sons, Great Britain.
- Rabenau, E., Fischer, H., Klein, W., September 1996, "Operations Concepts For Small Satellites - Results of a Workshop", *Proceedings, 10th Annual AIAA/USU Conference on Small Satellites* (www.satops.de/usu96.htm)
- Wertz, J. R., Wiley, L. J., 1991, *Space Mission Analysis and Design*, Kluwer Academic Publishers, USA.

ASRI reference documents are available at www.asri.org.au.

ECSS documents are available at www.estec.esa.nl/ecss.

2 PROPOSAL DESCRIPTION

2.1 OVERVIEW

At the dawn of the 21st century, Commercial-Off-The-Shelf (COTS) technology and solar electric propulsion (SEP) potentially enable exploration of interplanetary targets using low cost, lightweight spacecraft. Building on Australian expertise in remote sensing, telecommunications, and space applications, the Australian Lunar-Mars Investigation and Technical Evaluation (ALUMINATE) Project intends to design a generic spacecraft series for extra-earth orbital exploration and operations as far as three Astronomical Units (3AU) from the Earth, the approximate distance to the inner asteroid belt and within reach of Mars.

The ALUMINATE Project originated at the University of Queensland (UQ) in early 2000 with the Moon as the objective. However, preliminary analysis of the engineering requirements of such a venture suggested that Mars might be a more scientifically valuable and commercially viable target that could be reached without a dramatic increase in cost or engineering complexity. Analysis also suggested that Venus might be a viable alternative to Mars, particularly because of the substantially enhanced solar energy available to a spacecraft journeying to Venus as compared one journeying away from the Sun to Mars.

Noting this, the ALUMINATE Project will identify the most commercially-viable mission scenario, and then refine the generic spacecraft design to suit. The range of potential mission scenarios is shown in Table 1, with preliminary numerical analysis by project participants.

	Mission Concept																	
	Communications Relay						Remote Sensing						Remote Delivery					
Targets	A[1]	B[2]	C[3]	D[4]	E[5]	F[6]	A	B	C	D	E	F	A	B	C	D	E	F
Moon	3	2	3.25	4	4.5	3.35	4	4.5	4	3.25	3.75	3.90	4.25	4.75	5	3.75	2.25	4.00
Mars	4	2.5	3.75	3.5	3.25	3.40	4	5	4.5	3.25	3	3.95	4	5	5	3.25	2	3.85
Venus	1	1.75	3.5	4	3.5	2.75	3	4.75	4	4.5	3.25	3.90	3	5	4.75	4.25	1	3.60
NEO	1.5	2.25	3.5	4	3.25	2.90	3.75	4.75	4.5	3.5	3	3.90	3.75	5	4.75	4	2	3.90

Table 1. Potential ALUMINATE Mission Scenarios[7]

[1] Commercial viability
[2] Scientific reward
[3] Public appeal
[4] Initiative
[5] Technical complexity
[6] Totalled score
[7] ASRI-ALUM-E-MSS – *Mission Scenario Specification*, draft 0A.

Multi-mission and standardisation strategies will be investigated to speed development and reduce engineering complexity. Cost and risk will be reduced by designing a small spacecraft based on proven microsatellite concepts and by creating sub-systems from modular COTS components while making use of technologies such as intelligent agents to reduce operations personnel requirements.

Critically, the project also intends to actively engage the public and politicians for moral and material support for the realisation of at least one mission of the spacecraft series. This activity, termed ‘outreach’, is considered to be so important that a dedicated element of the project organisation is proposed.

At the end of Phase C – *Detailed Definition*[8] of this project, a Critical Design Review will be held. Based on the outcome of this review, the ASRI Board will decide if the project is to continue. If this continuation is approved, the project will proceed to manufacture, test, launch, operate and dispose of one or more of the spacecraft series. It is hoped that, should this happen, ASRI will be able to secure a launch for the identified mission.

[8] Refer ASRI Project System ‘project lifecycle’ at www.asri.org.au.

2.2 RATIONALE

2.2.1 *Reasons*

The reasons for undertaking the project are:

- To provide ASRI with expertise in extra-earth orbital mission design and management.
- To create an Australian ‘first’ that would provide a focus for national pride, technical achievement, and Australian exploration.
- To provide stimulus to the pursuit of space science in Australia.
- To provide training and experience in space vehicle design and space project management for highly motivated young professionals and students.

2.2.2 *Benefits*

The benefits of the ALUMINATE Project are:

- The contribution to the international exploration of space for peaceful scientific purposes.
- The identification of Australia with technical Australian space products, activities, services, and strengths.
- The strengthening of ASRI’s current national and international credibility.
- The promotion of ASRI’s capability to undertake complex space system projects.
- The utilisation of a defined space project system based on the ECSS, which will provide documents to extract trends, evaluate performance, and improve the ASRI Project System, and potentially, the ECSS.

2.2.3 *Initiative*

The ALUMINATE Project seeks to address a lack of interest in extra-earth orbital missions and, by adopting the ASRI Project System, prove that a volunteer, non-profit project can undertake complex space projects with public, scientific, and commercial rewards.

It is also novel for ASRI projects in that it includes an Outreach activity as part of its project organisation to actively engage students, professionals, the public and politicians for support through education and activities.

2.3 OBJECTIVES

2.3.1 Statement of Objectives

Completing the ALUMINATE Project up to a CDR at the end of Phase C would achieve the following objectives:

1. Prove that ASRI is capable of developing an extra-earth orbital space system.
2. Enhance the credibility of ASRI, and other involved organisations, both nationally and internationally.
3. Assist in the development and testing of the ASRI Project System.
4. Produce a tailored project system based on the ASRI Project System.
5. Present ASRI with a Detailed Definition for consideration to take to Production/Ground Qualification Testing.
6. Design a modular spacecraft series for extra-earth orbital exploration.
7. Create a skills base among young Australian professionals and students in areas of specialisation required by the project.
8. Develop strong relationships with other national and international space organisations.

2.3.2 Achieving Objectives

The identified objectives will have been achieved with the production of a set of deliverables and supporting material that passes the CDR. The result of a successful CDR is that the ALUMINATE Project will have produced a viable development proposal for an extra-earth orbital spacecraft and the design of an Australian generic modular spacecraft series for extra-earth orbital operations.

After the CDR, the ASRI Board would determine project continuation in consultation with other stakeholders.

2.3.3 *Failure to Achieve Objectives*

Objectives 1 to 6 will only be partially fulfilled if the project fails to pass the CDR.

Objectives 7 and 8 are achieved in increments with each successful formal review and phase exit. They should be considered a failure only if no project member finds full time employment in the Australian or international space industry as a result of the experience, skills, and exposure provided by the project.

2.3.4 *Preliminary Schedule*

The Phase 0 – *Mission Analysis/Needs Identification* exit review, known as a Mission Definition Review (MDR), is due for completion in October 2001 with an initial MDR being completed in June 2001.

The Phase A – *Feasibility* exit review, known as a Preliminary Requirements Review (PRR), is due for completion in late 2002.

The Phase B – *Preliminary Definition* exit review, known as a Preliminary Design Review (PDR), is due for completion in late 2003.

The ALUMINATE Project is intended to complete Phase C – *Detailed Definition* of the preferred mission scenario by late-2004, culminating in the CDR.

If approval from the ASRI Board and other mission-enabling factors are gained for continuation of the project after Phase C, the final build, testing, launch, and operations phases should begin in early 2005. Given an estimated one or two years for building and testing, a flight-ready model of the spacecraft could be ready by early 2007 for integration into a launch vehicle. This timeframe might allow ASRI to take advantage of the relationship with launch service provider ISC KOSMOTRAS that is being forged through the JAESAT microsatellite project.

The Phase D – *Production/Ground Qualification Testing* exit review, known as an Acceptance Review (AR), is expected to be complete by mid-2006.

The Phase E – *Utilisation* (sub-phase E1) exit review, known as an Operational Readiness Review (ORR), is expected to be complete by January 2007.

Table 2 describes the activities in each phase and the exit milestone. Where appropriate, the ECSS phase has been divided into two sub-phases. A Gantt chart of the project phases is shown Figure 2.

<table>
<tr><th>Phase</th><th>Milestone</th><th>Date</th><th>Description</th></tr>
<tr><td>Pre-Phase 0</td><td>ASRI Provisional Approval</td><td>May 2001</td><td>Iteration through ASRI Project System since definition. Although already provisionally approved, it follows the approval process to provide an example for future projects.</td></tr>
<tr><td>Phase 0_1</td><td>Mission Definition Review (MDR_1)</td><td>June 2001</td><td rowspan="2">The mission analysis and needs identification phase attempts to characterise the intended mission in terms of needs, expected performance, dependability, and safety. It should assess operating constraints and identify possible system concepts with attention given to critical aspects. It should also provide preliminary organisation, schedule, and cost models.

A two-phase MDR is proposed with MDR_1 used to ‘prune’ those target / mission concept permutations presented in Table 1 that are clearly infeasible within the project timeframe and likely resources. By doing so, the available analytical resources can be focused on thorough investigation of those more promising permutations.</td></tr>
<tr><td>Phase 0_2</td><td>Mission Definition Review (MDR_2)</td><td>October 2001</td></tr>
<tr><td>Phase A_1</td><td>Preliminary Requirements Review (PRR_1)</td><td>June 2002</td><td rowspan="2">The feasibility phase creates the final set of requirements and proposes solutions to the identified needs with specific reference to critical elements. It should establish the Function Tree (refer ECSS-M-10) and explore various system concepts with modelling of critical aspects and establishment of risks and levels of uncertainty. Finally it should estimate the technical and industrial feasibility of each concept by identifying constraints with respect to cost, time, organisation, utilisation, production, and disposal, including margins of error.</td></tr>
<tr><td>Phase A_2</td><td>Preliminary Requirements Review (PRR_2)</td><td>December 2002</td></tr>
<tr><td>Phase B_1</td><td>System Requirements Review (SRR)</td><td>June 2003</td><td rowspan="2">The preliminary definition phase selects technical solutions for the system concept approved in the PRR. At system level, the SRR is performed to provide a precise and coherent definition of the system, and provide initial identification of COTS alternatives for the system concept. It should also confirm the feasibility analysis performed in the previous phase.

Identification and assessment of risk reduction strategies should be undertaken as well as assessment of manufacturing, production, and operation costs and consultation between actors. Reliability, safety, and environmental assessments are included at this phase, and requirements should be traceable from high levels through all sub-systems. Specifications are established, including Design Justification Files.</td></tr>
<tr><td>Phase B_2</td><td>Preliminary Design Review (PDR)</td><td>December 2003</td></tr>
<tr><td>Phase C_1</td><td>Critical Design Review (CDR_1)</td><td>June 2004</td><td rowspan="2">The detailed definition phase enables the detailed study of the solution approved in the previous phase, production of representative elements of the system, determination of testing and qualification conditions, and final procurement plans to be made.</td></tr>
<tr><td>Phase C_2</td><td>Critical Design Review (CDR_2)</td><td>December 2004</td></tr>
</table>

Phase	Milestone	Date	Description
Phase D_1	Qualification Review (QR)	June/July 2005	*To be written…*
Phase D_2	Acceptance Review (AR)	June/July 2006	
Phase E_1	Operational Readiness Review (ORR)	January 2007	*To be written…*
Phase E_2	Flight Readiness Review (FRR)	?	*To be written…*
Phase F	Post Project Review (PPR)	?	*To be written…*

Table 2. Preliminary schedule summary

ID	Task Name	Start	Finish
1	Pre-Phase 0	Tue 7/11/00	Sat 2/06/01
2	Phase 0_1	Tue 5/06/01	Fri 29/06/01
3	Phase 0_2	Tue 3/07/01	Fri 26/10/01
4	Phase A_1	Tue 15/01/02	Fri 14/06/02
5	Phase A_2	Tue 2/07/02	Sat 23/11/02
6	Phase B_1	Tue 14/01/03	Sat 14/06/03
7	Phase B_2	Tue 8/07/03	Sat 22/11/03
8	Phase C_1	Tue 13/01/04	Sat 12/06/04
9	Phase C_2	Tue 13/07/04	Sat 20/11/04
10	Phase D_1	Mon 3/01/05	Sat 25/06/05
11	Phase D_2	Tue 5/07/05	Sat 24/06/06

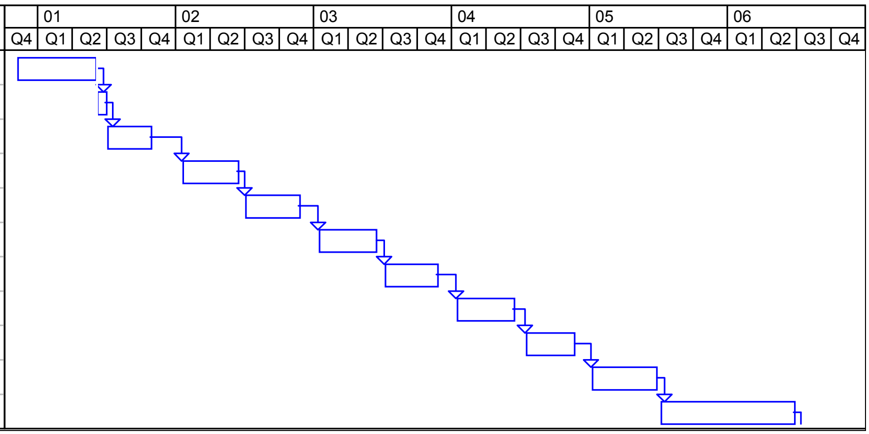

Figure 2. Preliminary project time-line

2.3.5 Objectives versus Rationale

Achieving the stated objectives addresses the project rationale, stated in Section 2.2, in a variety of ways, as summarised in Table 3.

Rationale Reasons/Benefits	Objectives							
	1	2	3	4	5	6	7	8
To provide ASRI with expertise in extra-earth orbital mission design and management	X	-	X	X	X	X	X	-
To create an Australian first that would provide a focus for national pride, technical achievement, and Australian exploration	X	X	-	-	-	X	-	X
To provide stimulus to the pursuit of space science in Australia	X	X	-	-		X	-	X
To provide training and experience in space vehicle design and management for highly motivated young professionals and students	X	-	X	X	X	X	X	-
The contribution to the international exploration of space for peaceful scientific purposes	-	-	-	-	X	X	-	X
The utilisation of a defined space project system based on the ECSS, which will provide documents to extract trends, evaluate performance, and improve the ASRI Project System and potentially the ECSS	-	-	X	X	X	-	-	-
The identification of Australia with technical Australian space products, activities, services, and strengths	X	X	-	-	-	X	X	-
The strengthening of ASRI's current national and international credibility	X	X	X	X	X	X	X	X
The promotion of ASRI's capability to undertake complex space system projects	X	-	X	X	X	X	-	X

Table 3. Objectives versus rationale

2.4 SYSTEM CONCEPT – GENERIC MODULAR SPACECRAFT PLATFORM

The ALUMINATE Project intends to investigate a variety of system concepts over the next three years to determine a generic system concept, known as the Generic Modular Spacecraft Platform (GMSP), and then specialise this system concept into communications relay, remote sensing, and surface payload delivery spacecraft.

The GMSP design concepts expressed in this document are based on the Preliminary Target Study[9], the Mission Scenario Specification[10], and additional research as listed in Section 1.7.

[9] ASRI-ALUM-E-PTS – Preliminary Target Study (to be released for MDR)
[10] ASRI-ALUM-E-MSS – Mission Scenario Specification (to be released for MDR)

The GMSP is intended to be a generic spacecraft platform for extra-earth orbital operations up to 3 AU from Earth. It will be composed of COTS components and provide a default (entry-level) platform for any small Australian extra-earth orbital mission within 3 AU from Earth. It will include a list of compatible payloads and preliminary instructions for specialisation of the platform, and modification of the payload adaptor. The GMSP will be, in essence, an off-the-shelf small satellite for interplanetary research.

A proposed system breakdown structure of the GMSP is shown in Figure 3. The segments and sub-systems are discussed in the appendix at Section 5.

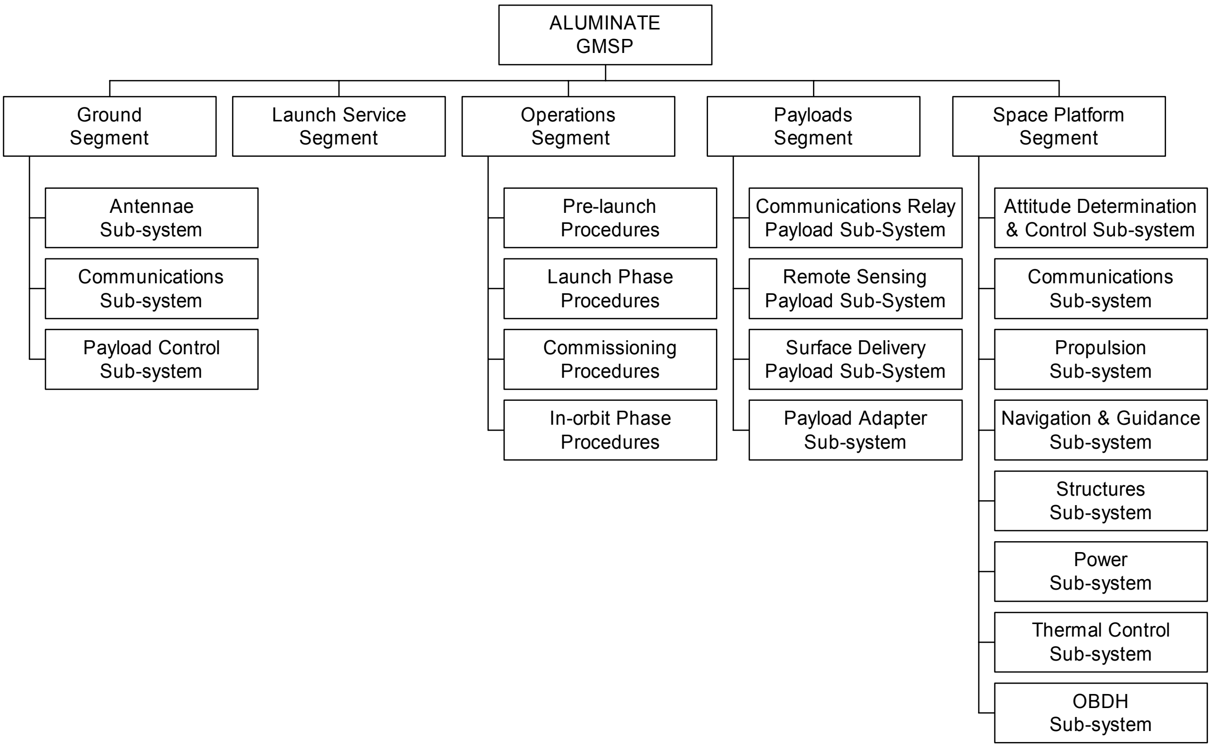

Figure 3. Proposed GMSP system breakdown structure

Additional design work will be required to specialise the spacecraft for its final target, however the core systems should be investigated and documented to allow easy implementation of a new spacecraft to suit a new mission scenario. Documentation should be prepared as “user manuals” for the modification and specialisation of the GMSP for a range of “plug-and-play” payloads with integration instructions.

2.5 SYSTEM DEVELOPMENT APPROACH

2.5.1 Constraints on the System Development Approach

The system development approach is necessarily limited by the project approach, which is premised on the use of volunteers, many of who will lack experience. For more information on the project approach, see Section 2.6.

2.5.2 Contemporary Approaches

There are three major contemporary spacecraft development approaches:

- Conventional sub-system-by-sub-system design
- Modular design for multiple missions
- Small Satellites Philosophy (SSP), which includes exchanging reduced cost for increased risk

The conventional design of a spacecraft sub-system by sub-system is where space exploration began. It produced spectacular craft designed for specific missions but, in most cases, for once-off use only. This approach was used because there was little heritage in space systems for modification or "plug and play" integration and international standards had not yet been developed. The conventional sub-system-by-sub-system design approach produced the most reliable spacecraft, but also, generally, the most expensive.

The modular design for multiple missions is generally based on a broad set of requirements drawn from a range of mission scenarios. In most cases, the sub-system design is then undertaken in a conventional sub-system-by-sub-system design approach. These modular systems usually have a standard system structure and bus with modular payloads, power, command and data handling, and attitude determination and control sub-systems. Examples of this approach can be seen in the joint NASA/Fairchild multi-mission spacecraft platforms used in the New Millennium, Discovery and SMEX programs, as well as the Iridium series, and Spectrum Astro's "MightySat".

The development approach of deploying small satellites provides a low cost solution with increased mission risk. It employs a few engineers to produce small satellites, typically 10 to 300 kg, for only a few million dollars each. Due to their small size, these satellites are also much cheaper and easier to launch. Small satellites provide access to space for groups who would otherwise be unable to afford a conventional satellite. Small satellite design recognises the need to trade total performance against total cost with lowest cost in mind.

2.5.3 “Smaller, Faster, Cheaper, Better”

2.5.3.1 Background

The Spacecraft Operations Oriented International Association (SpaceOps) was established in 1990 with representatives from most of the space-faring nations. The International Symposium on Space Mission Operations and Ground Data Systems is held every two years, with the first sponsored by the European Space Agency (ESA) in June 1990. The second, sponsored by NASA's Jet Propulsion Laboratory, was held in November 1992. The third was also sponsored by NASA in September 1994, and established the "Smaller, Faster, Cheaper, Better" motto for the symposium.

In recent years, this slogan has been wielded by many large aerospace organisations as the weapon that will make them viable in the economic environment of the early 21st century. Unfortunately, many of these organisations are still attached to their bureaucracy and fail in applying the principles.

2.5.3.2 Smaller

With the continued miniaturisation of electronics, improving efficiency rates of solar cells, and space structure and material science fields expanding, small spacecraft can now compete in commercial and scientific areas. The 300-kilogram concept of the GMSP is large enough to enable interplanetary trajectories from LEO, and provide entry-level communications, power, and payload facilities.

The smaller the size, the less complexity and the less extensive the mission operations and mission control crew. Small spacecraft can be run with highly automated systems requiring fewer personnel.

2.5.3.3 Faster

The idea of “faster” is not intended to be the use of better propulsion technologies, although this is a benefit. It is the adoption of specific strategies to organise a space project that minimises cost and time to flight.

It is expected that with the use of best practices and documented, repeatable processes, space projects can drastically reduce the time from concept to operation. By adopting an appropriate set of standards, such as the ECSS, and designing the ground station and spacecraft platform as modular, multi-mission systems, the project can evolve from design to operations rapidly.

2.5.3.4 Cheaper

To become competitive all spacecraft must make their operations cheaper. This can be accomplished by building a series of small spacecraft whose development and mission-independent costs can be shared across each mission. Operations costs can be reduced through autonomous operations and careful selection of the sequence of missions in the series.

With the development of generic spacecraft platforms and busses, it is cheaper, per spacecraft, to manufacture a dozen than to manufacture a few. The manufacturing of generic spacecraft platforms enables a series of spacecraft to be produced for interplanetary targets for as little as A$10 million each[11]. The spacecraft platform should be designed to work equally well (probably better) in a LEO environment, and for A$10 million each, this is a bargain for a 300-kilogram research satellite with an estimated five-year lifespan.

The produced spacecraft will take advantage of standardisation in communications and interfaces, project organisation, documentation and testing standards. It will use COTS components wherever practical and be developed from a minimal set of 'essential' requirements, thus reducing complexity. It will endeavour to use less people in design, development, manufacture, and operations with the goal to reduce both risk and cost.

2.5.3.5 Better

While adopting best practices may reduce the time from concept to launch and operation, this may do little to reduce the errors produced in a rushed or ill-conceived project or the untested or unqualified components from failing during the mission.

By adopting best practices, and accepting a commitment to producing a quality product that can compete on the international market, it is expected that the final spacecraft design will be the best quality it can be. By tracing requirements, formally documenting specifications, designs, justifications, and interface documents, and by developing accurate and efficient test and evaluation criteria the quality of the final product can be increased significantly.

A better spacecraft is also produced through the encouragement of innovative approaches within the bounds of realistic project and technical requirements and based on demonstrated facts and sound analysis. This innovation will make the spacecraft design better as well as the mission quality, and is where the personnel of the project can add the most value.

2.5.4 Preferred Development Approach

The ALUMINATE Project will attempt to adhere to the essence of the "Smaller, Faster, Cheaper, Better" approach as identified above. The spacecraft is designed to take advantage of the modular multi-mission approach and the small satellite approach to spacecraft system design. To

[11] This cost estimate does not include launch vehicle costs, currently estimated at $10 - $15 million per spacecraft launch.

limit development risk, the ALUMINATE Project will be designed with COTS equipment, both hardware and software, wherever practical.

In this manner, the ALUMINATE Project will be able to develop a high quality modular spacecraft for a low development cost. The spacecraft series could kick-start Australian space exploration and space science research.

2.6 PROJECT APPROACH

2.6.1 Overview

The project will be undertaken across several phases (each estimated to take one year to complete) with several iterations within each phase. The model of project phasing is defined as "evolutionary", and utilised when requirements are either not defined or elusive. Each iteration will be a “waterfall” process, such that one must finish before the next begins. A set of exit criteria will be selected for each iteration before the next iteration commences.

The project approach concept, shown in Figure 4, identifies roles, activities, and artifacts required for the successful completion of the project. Although not based on a specific project management approach, this is a standard project approach concept.

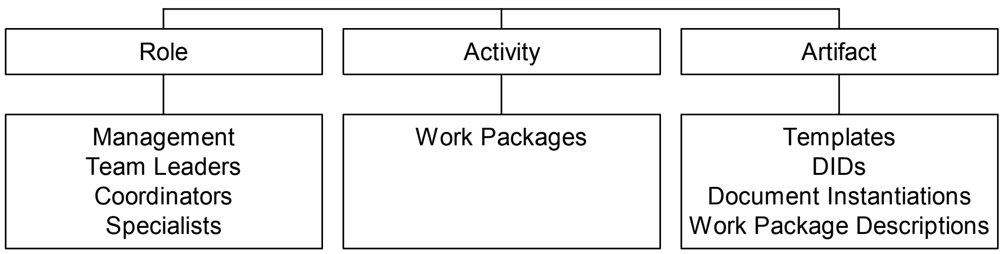

Figure 4. Project approach concept

The project is being resourced primarily out of volunteer team members drawn from a number of collaborating organisations (see the participants listed in Section 3.1). The specific project team skills requirements and competencies are identified in Section 3.8.

The ASRI Satellite Program Manager and the Project Manager are pursuing funding for the project, which is expected to come mainly from the corporate sector.

All positions are held for a period of three months from the start date. If measurable objectives have been set in correctly structured work packages, performance evaluations can take place based on the objectives defined in the work package. Each management position, from the Project Manager to coordinators, should be evaluated if an appropriate and unbiased process is approved.

2.6.2 Student Participation

With the perceived "brain drain" from the country, many space professionals are no longer in the country to provide support or guidance in the necessary background skills required for space project management and spacecraft mission analysis and design.

It is hoped that the use of the ECSS in the hands of a few professional management personnel with experience in the importance and implementation of standards systems will provide the training required for a cohesive and productive project. The rest of the project should be student run and implemented.

Undergraduate student participation should start from 2nd year and extend up to the level of Team Leaders. These positions should be documented in Work Package Descriptions, and accepted based on these descriptions. All positions are held on a three-month trial period, at which time the descriptions can be assessed against performance.

It is hoped to incorporate many technical work packages into the coursework of students. These technical work packages can be undertaken alongside management work packages (roles), and management work packages (roles) can be undertaken without contribution to technical work packages.

2.6.3 Advisory Panel

The project intends to raise an Advisory Panel to provide a wide range of technical, scientific, academic and management advice. Suggested Advisory Panel participants are listed in Table 4[12].

Ideally, the Advisory Panel would be in place before the completion of the Mission Definition Review (MDR). However, this is highly unlikely given the estimate for MDR being May 21st, although some suggested Advisory Panel participants would be asked to contribute to MDR on an individual basis. The Advisory Panel will continue to be developed specifically for review participation at major milestones and phase exits.

Further information on the Advisory Panel can be found in the *Stakeholder Requirements Document*[13].

Name	Contact	Organisation	Contacted	Interested
Internal				
Mark Blair		ASRI	No	Yes
Shaun Wilson		ASRI	Yes	Yes
Industry				
Ian Bryce		APSC	No	Yes

[12] Shaded entries represent Advisory Panel participants targeted for Mission Definition Review (MDR)
[13] ASRI-ALUM-M-SRD – *Stakeholder Requirements Document* (to be released at MDR)

Name	Contact	Organisation	Contacted	Interested
Roger Franzen		Auspace	No	?
Ian Tuohy		BAE SYSTEMS Australia	No	?
Dwight van Roy		Boeing Australia	No	?
Jeff Kingwell		CRCSS	No	Yes
John Boshier		IE Aust	No	?
Curtis Johnston		Kistler Aerospace	No	?
Gordon Pike		Optus	No	Yes
Jim Benson		SpaceDev	No	Yes
?		Spacelift	No	?
Martin Sweeting		SSTL	No	Yes
?		Telstra	No	?
Stephen Russell		VIPAC/FEDSat	No	Yes
Government				
Miriam Baltuck		NASA Representative	No	?
?		ESA Representative	No	?
?		NASDA Representative	No	?
?		RSA Representative	No	?
?		CSA Representative	No	?
?		CSIRO Radiophysics and Mineral Physics	No	?
?		COSSA (CSIRO Office of Space Science and Applications)	No	?
?		CRSC (Commonwealth Remote Sensing Committee – if still around)	No	?
Peter Kerr		DSTO (Defence Science Technology Organisation)	No	?
?		AUSLIG (ACRES – Australian Centre for Remote Sensing)	No	?
?		Bureau of Meteorology	No	?
Academia				
Rodney Buckland		University of Kent at Canterbury	No	Yes
Richard Morgan		University of Queensland	No	Yes
Salah Sukkarieh		University of Sydney	No	Yes
?		University of New South Wales	No	?
Pavel Trivailo		Royal Melbourne Institute of Technology	No	?
Miles Moody		Queensland University of Technology	No	?

Name	Contact	Organisation	Contacted	Interested
?		Australian Defence Force Academy	No	?
Other				
Jason Hoogland		Mars Society – Australia	Yes	Yes
Thomas Svitek	tomas@stin.com	?	No	?
?		NSSA	No	?

Table 4. Suggested Advisory Panel participants

2.6.4 *Funding and Finance*

2.6.4.1 Cash Funding

Cash funding will be encouraged with view to sponsorship for ASRI and its projects, inclusive of ALUMINATE. The current funding strategy is to acquire two ambassadors from either industry or government to financially support the ASRI microsatellite program, specifically those run from Queensland. A proposal is being prepared for the Premier of Queensland, as well as for key high-profile individuals.

2.6.4.2 Non-Cash Funding

Other options being investigated are in-kind "payment" for services, such as translating money or in-kind support into an ASRI service, such as an ASRI shirt, cap, or an ASRI organised "all-expenses-paid" trip to see sounding rocket tests. Other suggestions include ASRI organising contacts with overseas installations during visits as "payment" for outstanding service (ie. Gaining permission for members to visit Star City).

2.6.4.3 Financial Management

Financial records will be kept with a local account established to facilitate fund-raising activities and donation gathering. This account is considered a "working account", where any funds in excess of the identified budget expenses will be rolled over to ASRI for management and distribution to other projects. This will need to be formalised, and may still require negotiation.

Reimbursement for ASRI members outlay of money or in-kind support donated to the project, if any reimbursement, should take the form of tax-deductible receipts for approved project expenses. These receipts will be kept in a recognised format and justified before tax-deductible receipts will be issued by ASRI.

2.6.5 *Mission Enabling Factors*

The ALUMINATE Project aims to take the mission to a "green light" stage, the CDR at the end of Phase C, where construction of a series of spacecraft platforms can be undertaken with the specific intention of outfitting them for a series of interplanetary missions.

The Mission Enabling Factors (MEF) are defined as factors that will enable the "green light" stage to occur soon after confirmation, or a reasonable expectation of confirmation. There are four currently identified Mission Enabling Factors:

- A confirmed launch placement.
- Funding or in-kind support for a Critical Design Review by industry professionals and final detailed reworking (dependent on launch vehicle parameters, and expected to minimal).
- Funding or in-kind support for final phases of the mission to be implemented, such as production, ground qualification, launch, utilisation, and disposal.
- Funding or in-kind support for associated mission components including ground based telemetry systems, or ground stations and required software and data analysis.

Further MEF may be identified during the first few phases of the project.

2.6.6 Outreach campaign

The Outreach campaign is a non-technical campaign that will run alongside the technical elements of the ALUMINATE Project. This campaign will involve members of the public in discussions, activities, and education programs that are directly relevant to Australian space science and exploration. The Outreach campaign aims to produce support for the ALUMINATE Project, to increase the level of knowledge in the community about the opportunities provided by Australian space research, science and exploration, to encourage students to study in this and related areas, and to create a social climate that will encourage politicians to pursue a more educated and supportive role in the development of Australia's potential in this field.

The consumers of material produced by the Outreach campaign will be the general public, specifically students and teachers in all levels of education, interested members of the broader community, the media, and groups, organisations and companies who may have, or may develop an interest in, Australian space science and exploration. These categories are identified as:

- Student Division
- Community Division
- Interest Groups Division
- Media Strategy Division

These four general groups will have substantially different needs and requirements. It is believed that these needs and requirements will be best met by dividing the Outreach campaign into four divisions, utilising common resources wherever possible.

Further levels of participation are envisaged for the student division to include students from primary schools, high schools and tertiary institutions.

2.7 PROJECT ORGANISATION

2.7.1 Major Roles and Responsibilities

The proposed top-level project organisation is as per Figure 5. The major roles and responsibilities in this organisation are as follows:

- The Product Assurance Manager would assume primary responsibility for the management of team leaders and guidance in quality and safety of the project to ensure the final product is of the highest possible quality.

- The Strategic Planning Manager would assume primary responsibility for the management of team leaders and guidance in strategic issues relating to the strategic direction of support, outreach, and marketing.

- The System Engineering Manager would assume primary responsibility for the management of team leaders and guidance in technical systems engineering matters related to the spacecraft systems, including ground and launch segments.

- The Project Manager would run the day-to-day affairs of the project and be responsible for schedule achievement.

- The ASRI Satellite Program Manager, acting as the Project Director, would assume responsibility for resourcing and finance and be the primary interface to the launch service provider. This person would also provide direction, support and final authority as required either directly or through the Project Manager.

- The ASRI Board would act as the guiding authority for the project and would provide resources as needed within the capability of ASRI.

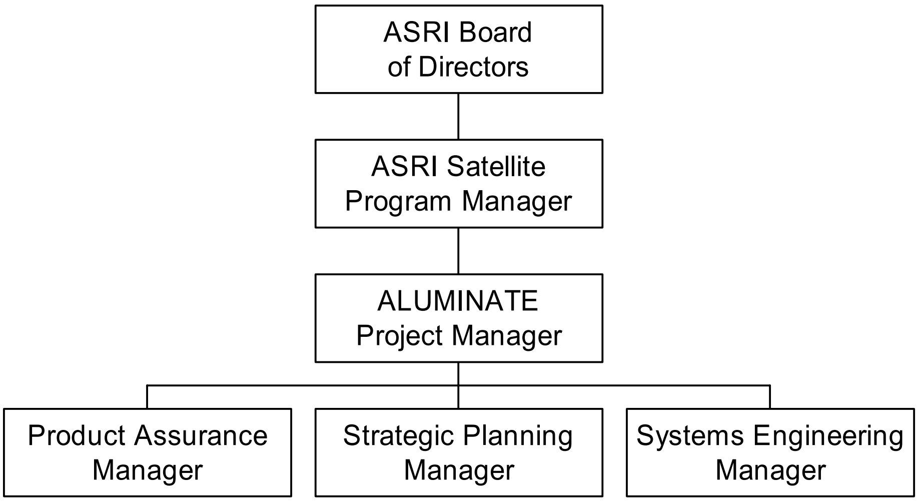

Figure 5. Proposed top-level project organisation

The ALUMINATE Project Executive comprises:

- ASRI Satellite Program Manager, acting as Project Director;
- ALUMINATE Project Manager;
- Product Assurance Manager;
- Strategic Planning Manager; and
- Systems Engineering Manager.

2.7.2 Extended Project Executive

Below the Project Executive, the management of the project is broken down into managers, team leaders, coordinators, and specialists. Together, these comprise the Extended Project Executive, which is shown in Figure 6.

Team Leaders would assume primary responsibility for the correct function and performance of the assigned segment or sub-system within the project schedule and financial budget. The team leaders beneath the Systems Engineering Manager and the Product Assurance Manager are the same positions, but different roles.

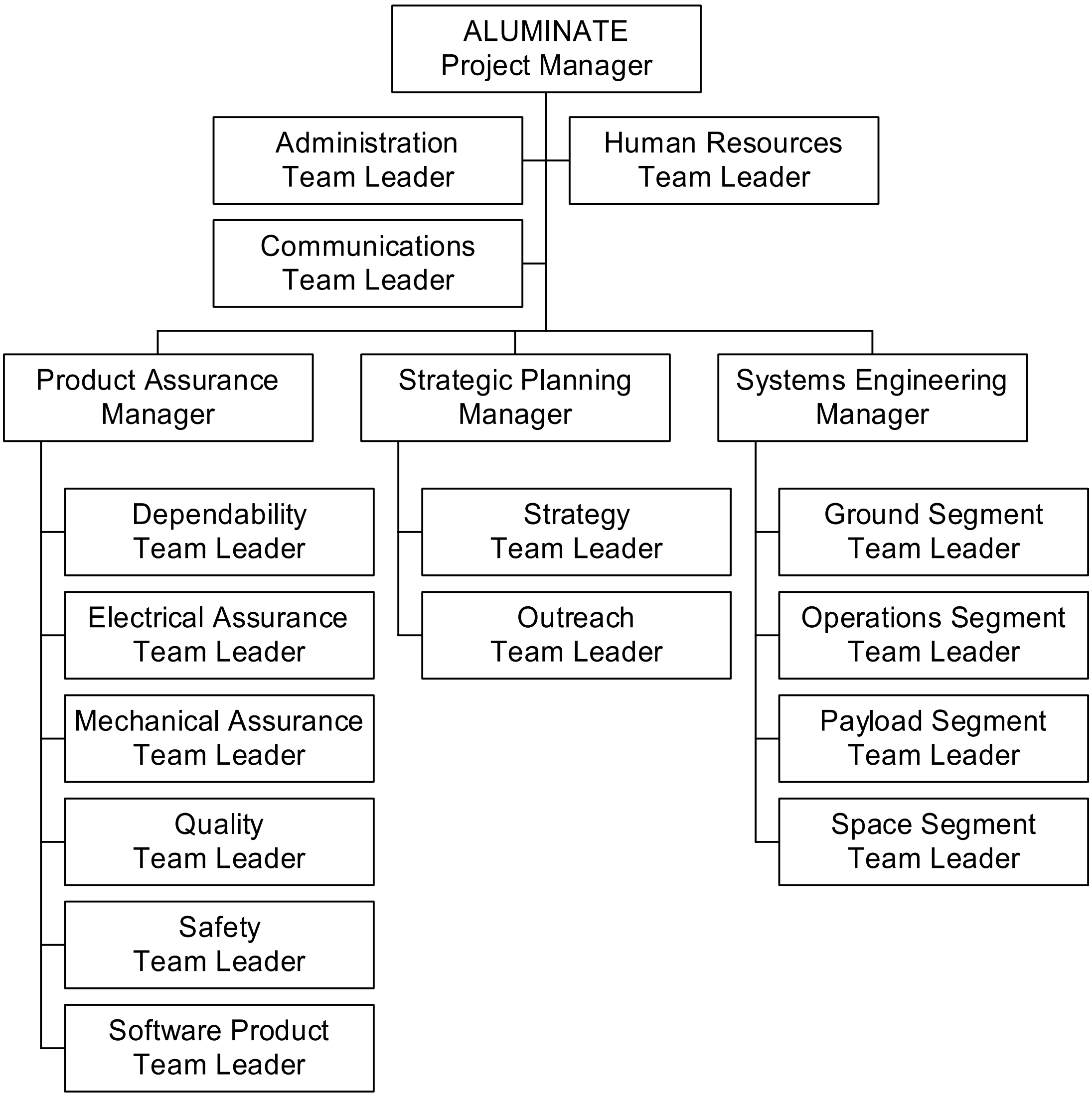

Figure 6. Proposed Extended Project Executive

2.7.3 Product Assurance

The proposed Product Assurance organisation is as per Figure 7. Further investigation will be required to identify the relevant coordinator positions.

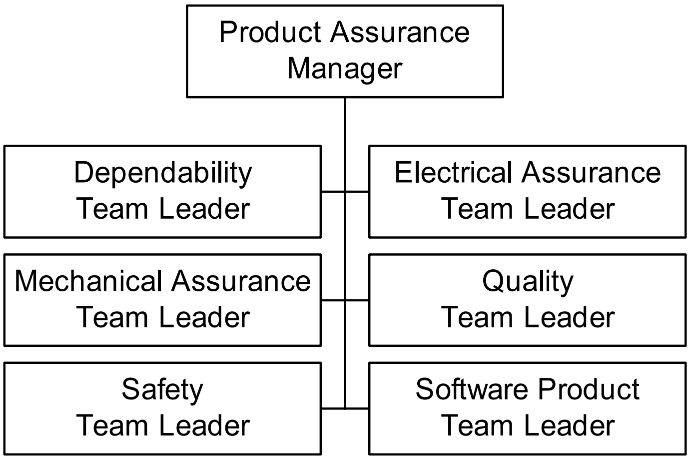

Figure 7. Proposed Product Assurance organisation

2.7.3.1 Dependability Team Leader

The Dependability Team Leader is responsible for a team of people who will coordinate the dependability assurance (reliability, availability, and maintainability) by identifying all technical risks with respect to functional needs and providing risk assessments and risk reduction and control strategies.

2.7.3.2 Electrical Assurance Team Leader

The Electrical Assurance Team Leader is responsible for a team of people who will coordinate the selection, control and procurement of electrical, electronic, and electromechanical components.

2.7.3.3 Mechanical Assurance Team Leader

The Mechanical Assurance Team Leader is responsible for a team of people who will coordinate the selection criteria of materials, mechanical parts and processes.

2.7.3.4 Quality Team Leader

The Quality Team Leader is responsible for a team of people who will coordinate the provision of adequate confidence measurements to the customer that the end product meets specified requirements.

2.7.3.5 Safety Team Leader

The Safety Team Leader is responsible for a team of people who will coordinate the safety of the flight and ground operations team, the general public, and public and private property, and the components comprising the end product.

2.7.3.6 Software Product Assurance Team Leader

The Software Product Assurance Team Leader is responsible for a team of people who will ensure that developed or reused software components satisfy the software requirements.

2.7.4 Project Management

The proposed Product Management organisation is as per Figure 8.

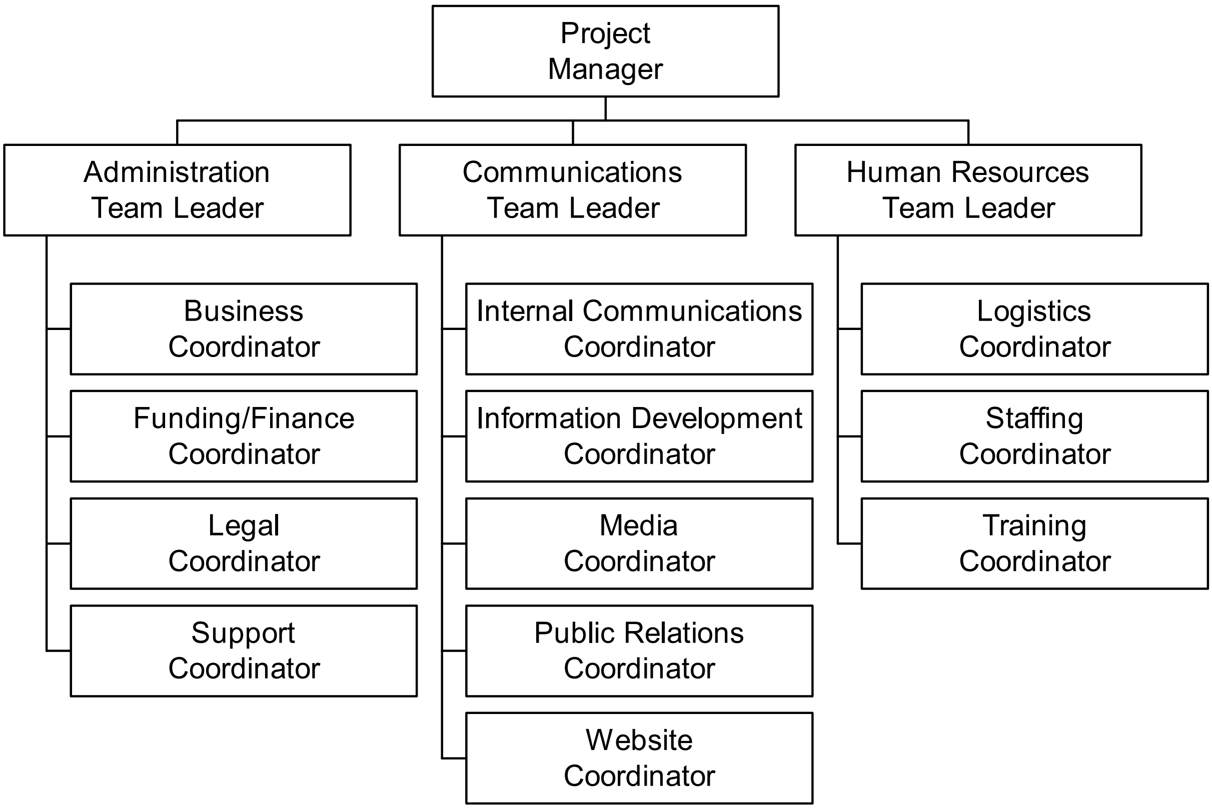

Figure 8. Proposed Project Management organisation

2.7.4.1 Administration Team Leader

The Administration Team Leader is responsible for a team of people who will coordinate the funding/financing of the project, as well as business analysis, legal, and other administrative support functions.

2.7.4.2 Communications Team Leader

The Communications Team Leader is responsible for coordinating a group of people who will research and lead the media and public relations areas, as well as investigating the information environment and requirements. The organisation and design of the website is included in this area, and the Communications Team Leader is also responsible for the internal communications of the project, such as minutes, status reports, and updates.

2.7.4.3 Human Resources Team Leader

The Human Resources Team Leader is responsible fore the team of people who will be recruiting and training project members in a variety of skills. The team will direct the increased competency of the contributing project members and provide training accordingly, as well as providing logistic support for personnel on project related activities.

2.7.5 Strategic Planning

The proposed Strategic Planning organisation is as per Figure 9. Further evolution of this structure may occur in the near future as organisational changes have been identified at the coordinator level.

The Strategic Planning Manager is responsible for planning the activities, tasks, and deliverables for their team leaders, and then assisting in the implementation of these plans. They should direct the team leaders in the strategic planning techniques and direction to enable the internal administration and external public endorsement of the project and final spacecraft design and mission plans. The Strategic Planning Manager is also responsible for the Outreach Campaign and the Human Resource aspects of the project.

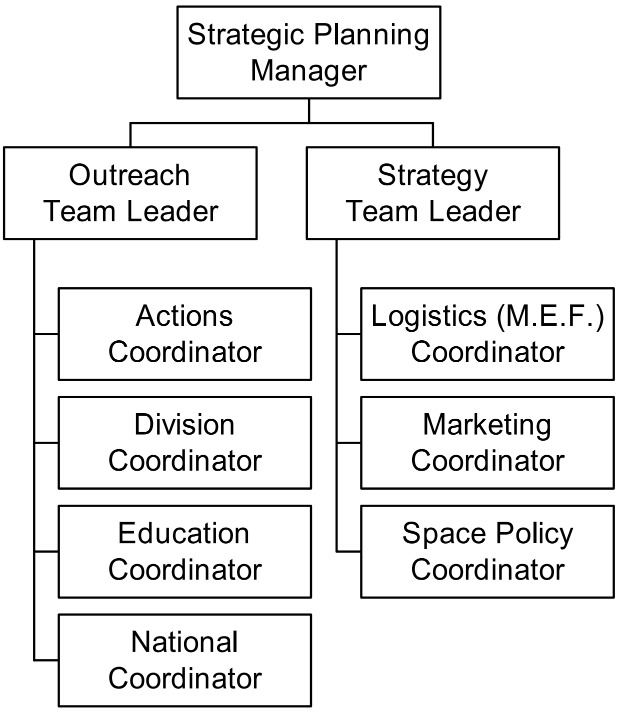

Figure 9. Proposed Strategic Planning organisation

2.7.5.1 Outreach Team Leader

The Outreach Team Leader is responsible for the direction of the Outreach campaign and the development of curriculum, including the direction and planning of the divisions, national coordination, and implementation of events and activities.

2.7.5.2 Strategy Team Leader

The Strategy Team Leader is responsible for the team of people who will define the strategic direction of the project and engineer the factors that will enable the project to continue to manufacture, launch, operation, and disposal. This team will research space policy and marketing directions and opportunities, as well as recommend actions that will provide the project with all Mission Enabling Factors.

2.7.6 Systems Engineering

The proposed Systems Engineering organisation is as per Figure 10. The Systems Engineering Manager is responsible for planning the activities, tasks, and deliverables for technical team leaders, and then assisting in the implementation of these plans. They should direct the team leaders in the systems engineering techniques and direction to enable the design of a complex integrated space system.

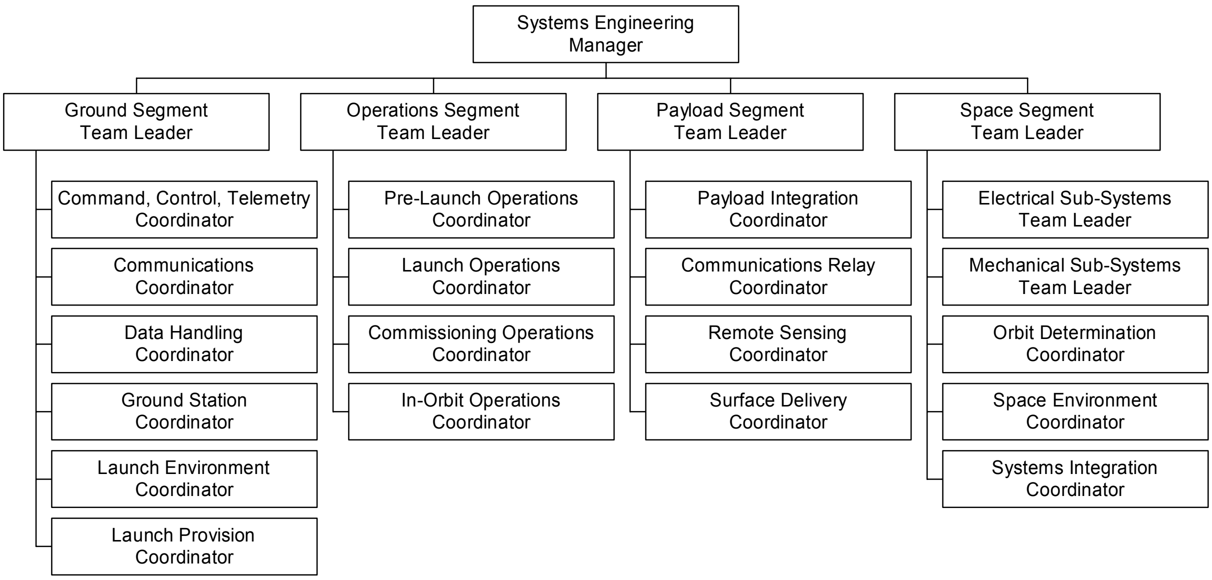

Figure 10. Proposed Systems Engineering organisation

2.7.6.1 Ground Segment Team Leader

The Ground Segment Team Leader is responsible for a team of people who will determine the number and location of ground stations, or alternative proposals for the utilisation of command, control, and telemetry. The team is also tasked with the research and design of efficient data handling and communications systems for the interaction between Earth and the spacecraft.

As the ALUMINATE Project is not designing a launch vehicle, the Ground Segment Team Leader is also responsible for leading a team of people to coordinate the launch provisions for the spacecraft, and for the research of the launch environment.

2.7.6.2 Operations Segment Team Leader

The Operations Segment Team Leader is responsible for a team of people who will research and design the operations phases for the spacecraft, from pre-launch testing and launch diagnostics to post-launch manoeuvring, deployment, and observation operations. More investigation is required to determine detailed tasks.

2.7.6.3 Payloads Segment Team Leader

The Payloads Segment Team Leader is responsible for a team of people who will research, document, and design compatible payloads for the designed space platforms. They will coordinate people toward designing specific payload streams of communications relay, remote sensing satellite, and surface delivery, as well as the integration of the payloads into the satellite platform.

2.7.6.4 Space Segment Team Leader

The Space Segment Team Leader is responsible for a team of people who will research and design the electrical and mechanical systems, including:

- Navigation and guidance (Elec.)
- Communications systems (Elec.)
- On-Board Data Handling (Elec.)
- Power systems (Elec.)
- Propulsion (Mech.)
- Thermal Control (Mech.)
- Attitude Determination and Control (Mech.)
- Structures (Mech.)

The Space Segment Team Leader is also responsible for the research and approval of orbit determination and reports on the space environment, as well as the systems integration aspects of the project.

3 PROPOSAL ANALYSIS

3.1 PARTICIPANTS

Organisation & contact(s)	Development involvement	Operation involvement	Benefits gained	Contribution to proposal
ASRI Shaun Wilson, Satellite Program Manager				Direction and guidance. Review prior to public release.
University of Queensland Centre for Hypersonics Richard Morgan	Provision of expert advice for formal reviews. Provision of students for mechanical engineering coursework activities.	?	Publicity.	TBD.
Queensland University of Technology (QUT) Prof Miles Moody (to be determined)	Provision of expert advice for formal reviews. Provision of students for coursework activities.	?	Enhanced reputation for aerospace avionics engineering.	?
University of Sydney Australian Centre for Field Robotics **Salah Sukkarieh** (to be advised)	Provision of expert advice for formal reviews. Provision of students for coursework activities in surface delivery.	?	Publicity	TBD.
Royal Melbourne Institute of Technology (RMIT) Dr Pavel Trivailo (to be determined)	Provision of expert advice for formal reviews. Provision of students for coursework activities. Provision of de-orbiting tether payload as a further test following from JAESat.	?	?	?
Dnipropetrovs'k National University, Ukraine (to be advised)	Payload teams Ground Station teams	Operation of backup control system.	Experience with microelectronics.	?

Organisation & contact(s)	Development involvement	Operation involvement	Benefits gained	Contribution to proposal
University of Kent at Canterbury **Rodney Buckland** (to be advised)	Provision of expert advice for formal reviews. Provision of students for coursework activities in surface delivery (adapting a surface penetrator).	Potential payload for surface delivery to the target.	Publicity Returned scientific data Validation of penetrator in interplanetary environment	TBD.
Cooperative Research Centre for Satellite Systems Dr Brian Embleton, Executive Director (to be advised)	Test & evaluation services: • Shake & bake • Thermal • Vacuum • EMI/EMC Required at component, sub-system and segment level	?	?	?
ISC KOSMOTRAS (to be determined)	Provision of launch environment and satellite / LV interface and integration information.	Launch of at least one of the ALUMINATE series.	Building a relationship with the Australian space industry that might result in paid-for follow-on launches.	Nil.
Institution of Engineers, Australia – National Committee on Space Engineering. Dr Ian Tuohy (to be determined)	?	?	?	?
Suzirya Protsan Yulian Apenko Olga	Facilitation of launch service provision. Ground Station teams Payload teams	Alternative control ground station.	?	?
Mars Society – Australia Jason Hoogland (to be determined)	?	?	?	?

Organisation & contact(s)	Development involvement	Operation involvement	Benefits gained	Contribution to proposal
Australian Students' Space Association Chris Beardmore (ASSA-UQ)	Provision of students for activities in all aspects of the project.	?	?	Preliminary technical studies

Table 5. Potential project participants by organisation

3.2 Profile

3.2.1 Sponsorship

Sponsorship will be sought to provide funding for the project and ASRI in general. Targets for sponsorship will be identified through the Strategic Planning section of the project during Phase 0, and will include individuals and organisations from industry, academia, and government. Relationships between the project or ASRI and the sponsors will be documented appropriately in business agreements or memoranda of understanding between parties.

3.2.2 Partners

Partners will be sought to provide funding and logistics for specific Outreach events and technology transfers. These partners will be identified during Phase 0.

3.2.3 Media Coverage

Media coverage is part of a concerted effort to educate and recruit by Strategic Planning. Weekly gatherings are currently being divided into technical sessions and general meetings for Phase 0. Australian space activity will be vocalised through these meetings and additional Outreach activity.

The ALUMINATE Project is committed to providing annual media attention during National Science Week, with the ultimate intention to organise multiple ASRI-related events around the country simultaneously. These events will all be worthy of media coverage, however the ability to organise and manage such events requires training of personnel and a defined strategy. This strategy will be based on the outcome of Phase 0 analysis.

3.3 Resources Required

3.3.1 People

A project team of approximately 65 people is estimated to be required for project completion up to Phase C - *Detailed Definition* exit. The team proposed consists of the individuals identified in Section 3.8. Currently, many positions identified require competent personnel to fill the roles, however, it is hoped that during the period of the project some of the personnel on the project will become competent in their fields.

3.3.2 Facilities

Facilities required include an office, phone, filing cabinet, and computer.

There is the potential for use of Workroom and (pseudo) clean room at QUT for post-Phase C - *Detailed Definition* activities.

Other facilities are yet to be identified and documented.

3.3.3 Services

The project requires ASRI to continue to provide web site and email services as per current arrangements.

3.3.4 Materials

No materials have been identified at this time; however, models of systems and components will be produced for education of team members and for Outreach activities.

3.3.5 Funding

3.3.5.1 Pre-Phase 0

Prior to being accepted as an ASRI project, and during the period between provisional approval and entry into Phase 0 under the ASRI Project System, the following amounts have been expended:

- Conference Attendance[14] - A$3500
- Promotional material - A$1000
- Communications (telephone calls, postage) - A$150
- Document production (photocopies, printing, clips, staples) - A$250

Retrospective payment of these expenses from ASRI funds, A$1400 excepting the A$3500 provided by UQCH, will be pursued separately.

3.3.5.2 Phase 0 – Mission Analysis

Due to the large amount of work conducted prior to formal Phase 0 commencement, this phase is only a few months long. Consequently, the funding requirements are minimal, as shown below:

[14] Provided by the UQCH.

- Conference Attendance – A$1000
- Promotional Material (UQ O-Week) - A$1000
- Communications (telephone calls, postage) - A$250
- Documentation production (photocopies, printing, clips, staples) - A$750
- National Science Week Display (transport, digitising footage, postage, display production) - A$500
- Outreach and Recruitment activities - A$1500

The total estimated expenditure for Phase 0 is A$5000. *ASRI Board approval for expenditure of this money on a reimbursement-if-available basis is sought as part of the provisional approval signifying Phase 0 commencement.*

3.3.5.3 Phase A – Feasibility

Phase A is almost entirely a paper study with funding required for:

- Conference Attendance – A$3500
- Promotional Material (UQ O-Week, QUT O-Week) - A$2000
- Communications (telephone calls, postage) - A$500
- Documentation production (photocopies, printing, clips, staples) - A$1000
- National Science Week Display 2002 (transport, digitising footage, postage, display production) - A$1500
- Outreach and Recruitment activities (incl. team building) - A$1500

The total cost of Phase A is therefore estimated to be approximately A$10,000.

3.3.5.4 Phase B – Preliminary Definition

Phase B is almost entirely a paper study with funding required for:

- Conference Attendance – A$7000
- Promotional Material (UQ O-Week, QUT O-Week) - A$4000
- Communications (telephone calls, postage) - A$1000
- Documentation production (photocopies, printing, clips, staples) - A$1000

- Displays (transport, digitising footage, postage, display production) - A$3000
- Outreach and Recruitment activities (incl. team building) - A$4000

The total cost of Phase B is therefore estimated to be approximately A$20,000

3.3.5.5 Phase C – Detailed Definition

Phase C is almost entirely a paper study with funding required for:

- Conference Attendance – A$15000
- Promotional Material (UQ O-Week, QUT O-Week) - A$5000
- Communications (telephone calls, postage) - A$2500
- Documentation production (photocopies, printing, clips, staples) - A$5000
- Displays (transport, digitising footage, postage, display production) - A$5000
- Outreach and Recruitment activities (incl. team building) - A$5000
- Administration expenses (software, services) - A$5000
- Model construction - A$7500

The total cost of Phase C is therefore estimated to be approximately A$50,000

3.3.5.6 Phase D Onwards

The total project budget from Phase D up to launch and operation is estimated to be between A$20 million and A$60 million[15].

These estimates will be refined as work progresses.

3.3.6 Other Support

Other support requirements will require identification.

3.4 SYNERGIES

There is an immediate synergy with the other project in the ASRI Satellite Program – the Joint Australian Engineering Satellite (JAESAT). Elements of

[15] This estimate is based on a survey of current missions and launch vehicle costs for non-dedicated launch services.

this synergy include common processes, experience in undertaking a space-engineering project in the private sector and logical progression through rising technical complexity.

The ALUMINATE Project is also piloting the ASRI Project System, which will benefit future ASRI projects, with immediate benefit to existing ASRI projects from document and template use.

3.5 COMPETITIVE ENVIRONMENT

3.5.1 National Competitive Environment

As there is no Australian space program, the national competition is purely in satellite technology areas rather than the mission concept of sending a spacecraft to another planetary body. All competing satellites are substantially smaller than the intended 300 kg spacecraft platform

Name & location	Project description	Advantages	Limitations
FedSat Cooperative Research Centre for Satellite Systems (CRCSS)	Development of a 58kg three-axis stabilised research satellite by the CRCSS (funded program of approximately A$18M)	More technologically advanced platform Government backed program with interfaces to universities	Lack of clear objective Lack of follow-on program Big ‘science budget’ mentality to resourcing Tied to unproven launch vehicle with launch date uncertainty
BLUESat University of New South Wales	12kg LEO (Low Earth Orbit) AMSAT cube bus	Developed by student-based group Expertise in solar cells	Lack of extensive cooperation Lack of professional full time staff
JAESAT Australian Space Research Institute Ltd.	15kg LEO (Low Earth Orbit) AMSAT cube bus	Developed by student-based group Piloting a standard space project management system	Technical initiative hampered by launch deadline Lack of professional full time staff

Table 6. National competitive environment

3.5.2 International Competitive Environment

With the recent change in attitude of the US toward space exploration, the international competitive environment has become a lot more competitive from a small interplanetary satellite standpoint. With the Mars Sample Return mission slipping back to at least 2011, more likely 2014, volunteer groups have the potential of competing with the giants of space exploration.

The International competitive environment is summarised in Table 7. A key part of Phase 0 is to identify more international missions that may be competing with the ALUMINATE Project. The advantages and limitations will be completed for Phase 0 exit.

Name & location	Project description	Advantages	Limitations
Moon			
SMART-1	Mission to validate SEP for ESA, and perform lunar surface imaging, undertake lunar mineralogy investigation, and surface elemental composition studies.		
Lunar-Retriever	Marketing organisation intending to raise support for a lunar sample return mission.		
Selene	An EU lunar remote sensing mission.		
Mars			
Global Surveyor	Mission to map the entire planet at high resolution, and gather data on the surface morphology, topography, gravity, weather and climate, surface and atmospheric composition, and planetary magnetic field. It will also provide relay communications for future Mars missions.		
Mars Odyssey	Mission to map the mineralogy and morphology, elemental composition of the surface, and the Martian near-space radiation environment		
Nozomi	Mission to study the upper atmosphere and its interaction with the solar wind and to develop technologies for use in future planetary missions, under direction of the Japanese Institute of Space and Astronautical Science (ISAS).		

Name & location	Project description	Advantages	Limitations
Mars Express	Mission to search for sub-surface water from orbit and drop a lander (Beagle 2) on the surface. Remote sensing experiments intend to investigate the atmosphere, planet's structure and geology.		
Venus			
?			
NEO			
Deep Space 1	Mission to test SEP, autonomous navigation system, advanced microelectronics and telecommunications devices. Encountered near-Earth asteroid (9969 Braille) and a Comet (Borrelly)		
MUSES-C	An asteroid (1998 SF36) sample return mission being mounted by the Japanese Institute of Space and Astronautical Science		
Rosetta	Mission to rendezvous with a comet (46 P/Wirtanen), and flyby two asteroids (Otawara and Siwa).		

Table 7. International competitive environment

3.6 ASSUMPTIONS

Ser	Assumption	Rationale / Basis	Impact if not correct
1	That sufficiently skilled personnel can be found to design the space system.	Australia has skills in key technical areas and few barriers to technology transfers with skilled nations	Substandard spacecraft designed Delays in schedules and cost

Ser	Assumption	Rationale / Basis	Impact if not correct
2	That an industrial base exists within Australia to provide industrial expertise.	Australia is about to start commercial launch operations Australia has provided continuous quality support services to other space programs	Lack of mentoring for personnel Increases in cost due to lack of industrial "know-how"
3	That sufficient funding can be found to select and design the space system.	Project aims to select and design for minimal cost Public and commercial support exists for adequate funding opportunities	Delays in schedules or project termination Enhancement of organisation and distribution
4	That commercial viability exists within the scope of the space system.	Many international student projects with similar sizes and targets Commercial spin-offs from research and university endeavours are lucrative Commercial entities exist with this market	Downscale scope of project to focus on LEO Target research/civilian use of the space system
5	That international trends will support the space system design approach.	Miniaturisation continues Launch vehicle costs decreasing Autonomous systems drastically reduce cost International standards will support backward compatibility	There will be few standard "plug and play" payloads for the designed space system Project termination or delay in schedules
6	That the project is unique in Australia.	No other extra-earth orbital missions have been identified from Australia Management standards are not applied to student projects	Division of public support or increase of public support Identification of mission profiles urgent to provide the project with a "character" for the public
7	That an extra-earth orbital design project will enhance Australian space industry.	Trend in "brain drain" Decreasing international recognition for Australian space activities and support services	Continuation of "brain drain" Redefinition of project scope
8	That the Australian public want Australia to explore space.	Widespread public support	Lack of participation and educational attendance Lack of funding or other support
9	That an extra-earth orbital design project will enhance Australian technical capability.	Trend in "brain drain" Decreasing international recognition for Australian technical capability	Continuation of "brain drain"

Table 8. Assumptions

3.7 DEPENDENCIES

Ser	Dependency	3rd Party	Impact if not met
1	Provision of enthusiastic students for coursework activities	Relevant universities	Project termination or delay in schedule and increase of costs
2	Provision of experienced industry professionals for review of produced material	Advisory Panel participants	Substandard design and documentation leading to increased costs and delays in schedule
3	Provision of sufficient funding	Sponsoring organisations and project personnel	Delays in schedule or project termination
4	Continued ASRI support and guidance	ASRI	Project termination or substandard design

Table 9. Dependencies

3.8 PROJECT TEAM SKILLS [16]

Skill	Required		Offered by own team		Alternatives
	Level	Qty	Individual	Level	
Project management	Comp	1	Cameron Boyd	Novice	Other PM drawn from ASRI membership
Product assurance management	Comp	1	Cameron Boyd	Comp	Richard Poole ?
Strategic planning management	Comp	1	Rob Sturgess	Comp	
Systems engineering management	Comp	1	Richard Poole	Comp	Yulian Protsan ?
Dependability assurance Team Leader	Comp	1			
Electrical assurance Team Leader	Comp	1			
Mechanical assurance Team leader	Comp	1			
Quality assurance Team Leader	Comp	1			
Safety assurance Team Leader	Comp	1			

[16] "Comp" is a person with a completed advanced degree, or industry experience in a relevant field; "Novice" is a person with little or unrelated experience in a relevant field.

Skill	Required		Offered by own team		Alternatives
	Level	Qty	Individual	Level	
Software product assurance Team Leader	Comp	1			
Administration Team Leader	Comp	1			
Communications Team Leader	Comp	1			
Human Resources Team Leader	Comp	1			
Outreach Team Leader	Comp	1	Kala Perkins	Novice	Jane Davis ?
Strategy Team Leader	Comp	1			
Ground Segment Team Leader	Comp	1	Andrew Fenton	Novice	
Operations Segment Team Leader	Comp	1	Llewellyn Mann	Novice	
Payload Segment Team Leader	Comp	1	Chris Beardmore	Novice	
Space Segment Team Leader	Comp	1	Sean O'Gorman	Comp	
Mechanical Sub-System Team Leader	Comp	1	Patrick Doody	Novice	
Electrical Sub-System Team Leader	Comp	1			
Business Coordinator	Comp	1			
Funding/Finance Coordinator	Comp	1			
Legal Coordinator	Comp	1			
Support Coordinator	Comp	1			
Internal Communications Coordinator	Comp	1			
Information Development Coordinator	Comp	1			
Media Coordinator	Comp	1			
Public Relations Coordinator	Comp	1			
Website Coordinator	Comp	1	Don Burgess	Comp	
Logistics Coordinator	Comp	1			
Staffing Coordinator	Comp	1			

Skill	Required		Offered by own team		Alternatives
	Level	Qty	Individual	Level	
Training Coordinator	Comp	1			
Actions Coordinator	Comp	1			
Division Coordinator	Comp	1			
Education Coordinator	Comp	1			Shellaine Godbolt ?
National Coordinator	Comp	1			
Logistics (M.E.F.) Coordinator	Comp	1			
Marketing Coordinator	Comp	1			
Space Policy Coordinator	Comp	1			
Command, control, telemetry Coordinator	Comp	1			
Communications Coordinator	Comp	1			
Data handling Coordinator	Comp	1			
Ground station Coordinator	Comp	1			
Launch environment Coordinator	Comp	1	Jason Langenaur ?		
Launch provision Coordinator	Comp	1			
Pre-Launch operations Coordinator	Comp	1			
Launch operations Coordinator	Comp	1			
Post-Launch operations Coordinator	Comp	1			
In-Orbit operations Coordinator	Comp	1			
Payload integration Coordinator	Comp	1			
Communications relay Coordinator	Comp	1			
Remote sensing Coordinator	Comp	1	Richard Walaker	Comp	
Surface delivery Coordinator	Comp	1	Salah Sukkarieh	Comp	

Skill	Required		Offered by own team		Alternatives
	Level	Qty	Individual	Level	
Propulsion Coordinator	Comp	1	Matthew Lynch	Novice	
Thermal control Coordinator	Comp	1			
Attitude determination and control Coordinator	Comp	1	Brett Robertson	Comp	
Structures Coordinator	Comp	1			
Navigation and guidance Coordinator	Comp	1			
Communications Coordinator	Comp	1			
On-Board data handling Coordinator	Comp	1			
Power Coordinator	Comp	1			
Orbit determination Coordinator	Comp	1	Christina Riley	Novice	Jason Hoogland
Space environment Coordinator	Comp	1	David Hartley	Novice	
Systems integration Coordinator	Comp	1			

Table 10. Project team skills summary

3.9 RISK MANAGEMENT

A formal risk assessment is required by ASRI to facilitate the effective management of risk throughout the life of the project. This assessment is in accordance with Table 11, which is derived from the Australia and New Zealand standard AS/NZS 4360:1999 – *Risk Management*.

	Consequence				
Probability	*1 Insignificant*	*2 Minor*	*3 Moderate*	*4 Major*	*5 Catastrophic (Mission kill)*
5 Near certain	High	High	Extreme	Extreme	Extreme
4 Likely	Moderate	High	High	Extreme	Extreme
3 Moderate	Low	Moderate	High	Extreme	Extreme
2 Unlikely	Low	Low	Moderate	High	Extreme
1 Remote	Low	Low	Moderate	High	High

Extreme risk – mission-critical – immediate action required
High risk – senior management attention needed
Moderate risk – management responsibility must be specified
Low risk – manage by routine procedures

Table 11. Qualitative risk analysis matrix for level of untreated risk

Table 12 describes the major risks that the project faces and assesses the level of 'untreated risk' as per Table 11. The indicators and proposed remediation or mitigation measures for each identified risk are described in Table 13 along with the resulting level of 'residual risk'.

Ser	Risk Description	Prob	Consequence Description	Level	Untreated risk level
Management Risks					
M1	Project organisation collapses	3	Project termination or extended delay leading to missed launch opportunity	5	Extreme 15
M2	Unable to obtain sufficient funding when required	4	Extended delay leading to missed launch opportunity	4	Extreme 16
M3	Loss of key personnel	3	Extended delay leading to missed launch opportunity	4	Extreme 12

Ser	Risk		Consequence		Untreated risk level
	Description	Prob	Description	Level	
M4	Unable to complete project within budget and schedule	4	Extended delay leading to missed launch opportunity	4	Extreme 16
M5	Unable to obtain sufficient personnel when required	4	Extended delay leading to missed launch opportunity	4	Extreme 16

Table 12. Assessment of untreated risk level

Ser	Untreated risk level	Indicator(s)	Mitigation / Remediation	Residual risk level
Management Risks				
M1	Extreme	Disagreements Work Packages not completed on schedule or at all	Ongoing liaison between participating organisations Clear alignment of project objectives with stakeholder objectives in *Stakeholder Requirements Document* (SRD)[17].	Extreme
M2	Extreme	Promised funding not available at start of project Cash flow becomes tight during project	Multiple funding sources Source more *potential* funding than absolutely required	Extreme
M3	Extreme	Work packages not completed on schedule or at all	Ongoing liaison between participating personnel and management of workload	High
M4	Extreme	Schedule slippage and cost above projected at given point in project	Thorough cost and time estimates with sufficient contingency to cover assessed risks Active management of development process Use of COTS equipment, preferably already space-experiences	Extreme
M5	Extreme	Work Packages not completed on schedule or at all Schedule slippage and cost above projected at given point in project	Actively engage recruitment for project activities Maintain a multi-skilled core of project personnel Integrate work packages with academic requirements	Extreme

Table 13. Assessment of residual risk level

Note that the residual risk levels shown in Table 13 for management risks generally remain 'extreme' despite the proposed mitigation / remediation

[17] ASRI-ALUM-M-SRD – *Stakeholder Requirements Document* (to be released for MDR)

measures. This reflects the ambitious and pioneering nature of the ALUMINATE Project.

4 PROGRESS AND ASSESSMENT

4.1 PROCESSING

Proposal coordinator: **Cameron Boyd**

Director sponsor: **Shaun Wilson**

Date	Action	Outcome and comment
2001-05-07 2001-06-04 2001-06-09	Draft PPR received by sponsor Received as ver0D Sent to Board as ver0E with sponsor comments	Revised to ver0C and sent back to ALUMINATE Executive for concurrence. Sponsor comments: • Proposal is ambitious and risky, but well thought out. • Schedule has been designed to ensure adequate research before commitment of significant resources. • Target (Moon, Mars, Venus or NEO) will be determined early in Phase 0 at the first MDR. • Note Section 3.3.5 re funding, especially pre-Phase 0 and Phase 0 funding. Sponsor recommendation to Board is to provisionally approve ALUMINATE, thus triggering commencement of Phase 0.
2001-06-09	Draft PPR received by ASRI Board as ver0E	
	ASRI Board provisional approval	Decision: GO / NO Phase 0 budget: $5000
	Phase 0 started	
	Mission Definition Review	
	Phase 0 exit documentation received by sponsor	
	Phase 0 exit documentation received by ASRI Board	
	ASRI Board formal approval	Decision: GO / NO
	Phase A started	

Table 14. Progression through project approval process

4.2 PRE-APPROVAL ISSUES

Table 15 lists those issues raised by the ASRI Board members, and others, during the project approval process.

Date	Issue	Response	Status

Table 15. Pre-approval issues

5 APPENDIX – GMSP CONCEPT DESCRIPTION

5.1 GROUND SEGMENT

5.1.1 Overview

With an estimated flight readiness date of early 2006, plans need to be made as to how communications to and from the spacecraft will be dealt with. Further investigation is required to see if Australia has the ability to meet ground station and communications requirements alone. It is expected that other ground stations will be required around the world. Opportunities exist to broaden international cooperation for future ASRI projects.

5.1.2 Antenna Sub-System

The potential use of Australian antenna needs to be investigated and it is expected that alternative antenna will need to be identified. Potential exists to use the first LEO test mission as a communications backup for the interplanetary mission/s. Specific attention will need top be given to specific missions, and the satellite antenna sub-system for interfacing.

5.1.3 Communications Sub-System

The communications sub-system will attempt to adhere to Consultative Committee for Space Data Systems (CCSDS) standards, where applicable, and will be interfacing with the electrical communications of the satellite system.

5.1.4 Payload Control Sub-system

The payload control sub-system enables the control and tasking of payloads on the spacecraft and return of payload data.

5.2 LAUNCH SERVICE SEGMENT

A launch for the GMSP-based spacecraft could potentially be provided by ISC KOSMOTRAS using a Dnepr-1 / Dnipro-1 launch vehicle, a converted SS-18 SATAN ICBM.

The current cost for use of this launch vehicle for deployment of the ALUMINATE satellite is approximately A$20 million per launch[18], but at least two spacecraft of the same size can be launched with each launch vehicle.

Primary analysis will be given to the Dnepr-1 / Dnipro-1 launch vehicle as provided by ISC KOSMOTRAS for launch environment parameters, however additional launch vehicles will be identified and analysed. These parameters will be based on the research undertaken by JAESAT.

[18] This figure is from old text sources and is being verified by launch service providers.

It is expected that after feasibility analysis of the potential launch services several launch vehicles will be identified as potential candidates. Information on launch vehicle payload shrouds are required immediately for identifying the permissible spacecraft volume envelope.

5.3 OPERATIONS SEGMENT

5.3.1 Overview

Operations should be introduced into the project design loop as early as possible. The operations segment interacts with the ground segment in the infrastructure, hardware, and software to prepare, test, conduct, and support required mission operations. It should provide an Operations Manual outlining the procedures for operating and controlling the spacecraft.

5.3.2 Pre-Launch

The Pre-Launch operations should include the range of test and stowing operations required for the spacecraft to perform prior to being launched. Further investigation is required to determine whether this includes operations after integration with the launch vehicle but prior to launch, if any.

5.3.3 Launch

During launch the spacecraft may require minimal operations for readiness of launch vehicle separation and deployment.

5.3.4 Commissioning

A set of commissioning procedures will need to be established to identify operations required for commissioning the spacecraft after deployment. In many cases where the satellite is for a customer, the customer will not accept the spacecraft handover until the commissioning procedures have been completed satisfactorily.

5.3.5 In-Orbit

The operations required for operating the spacecraft during cruise and operations at the target have yet to be identified.

5.4 PAYLOADS SEGMENT

5.4.1 Overview

The payload segment is a generic module that will hold payloads for communications relay, remote sensing, or surface delivery. This will be accompanied with a set of COTS payloads that can be used with the payload module and adaptor.

Although the structure of the spacecraft has yet to be determined, the conceptualisation of these sub-systems as modules leads to further conceptual design work to determine requirements.

5.4.2 Communications Relay

This payload concept is outlined on the Mission Scenario Specification (ASRI-ALUM-E-MSS[19]).

5.4.3 Remote Sensing

This payload concept is outlined on the Mission Scenario Specification (ASRI-ALUM-E-MSS[19]).

5.4.4 Surface Delivery

This payload concept is outlined on the Mission Scenario Specification (ASRI-ALUM-E-MSS[19]).

5.4.5 Payload Adaptor

The payload adaptor is either a software interface or a hardware interface (or a combination of both) with the spacecraft bus and standardised systems (telecommunications – CCSDS; connectors – ISO; engineering – ECSS). This enables a “plug and play” interface for many of the identified payloads, with troubleshooting advice (and perhaps tools) on integrating novel payloads.

The payload adaptor is conceptualised as a panel with three parallel sets of ports and connectors on both sides. One side interfaces with the spacecraft cables and structure. The other side interfaces with specific payloads. One set of connectors could be connected to the rotating payload module, another set of connectors could be connected to a deployment bay module for surface/atmospheric delivery of payloads, and another set could be connected to a communications module.

5.5 SPACE PLATFORM SEGMENT

5.5.1 Space Environment Parameters Specification

The space environment needs to be determined soon, as it will effect all aspects of the spacecraft design. As an example, the thermal environment for orbit around Mars can vary from between -100°C and +150°C, and this dictates certain thermal control measures.

[19] ASRI-ALUM-E-MSS – *Mission Scenario Specification* (to be released at MDR)

5.5.2 Orbit Determination Parameters Specification

Based on identified launch vehicles baseline orbit determination is still required for each of the targets identified. NEO targets still need identification and launch windows have yet to be established. Preliminary analysis has provided mass and power estimates based on local proximity rather than orbital analysis.

5.5.3 Mechanical Sub-System

5.5.3.1 Overview

The mechanical sub-system is broken into attitude determination and control, propulsion, structure, and thermal control.

5.5.3.2 Attitude Determination and Control

To communicate with the Earth up to 3 AU away and perform remote sensing or payload delivery operations a high degree of pointing accuracy will be required. It is estimated that 0.15° should provide sufficient pointing accuracy for communications to Earth, and for any remote sensing payloads.

To enable this pointing accuracy, star trackers and sun sensors will be employed to calculate the orientation of the spacecraft. It has also been recommended to use reaction wheels to make small changes in the spacecraft orientation. More investigation will need to be undertaken to determine the requirements for autonomous navigation and guidance (smart satellite).

Corrections to the spacecraft's trajectory during cruise will be made by firing two or more of the estimated eight attitude control thrusters placed at each corner of the platform. The attitude control thrusters may be used as a back up in case of main engine failure, and may also be used for pointing and attitude control.

5.5.3.3 Propulsion

The spacecraft is expected to be launched into Low Earth Orbit (LEO) and make its way from LEO to its identified target using SEP.

The main engine should be capable of delivering around 400N of thrust, using a bipropellant mixture, and may use orbital oscillations to place itself on a trajectory to its identified target.

5.5.3.4 Structure

The spacecraft structure is designed to take at least 15 kgs of payload to an extra-earth orbital target.

Further investigations hope to maximise the size and weight of potential payload area, with a target improvement of 35 kgs (50 kgs payload).

The total fuelled spacecraft weight shall not exceed 300 kgs. This should enable the spacecraft to be launched from either an Ariane 5 ASAP, or a Ukrainian Dnepr-1. In both cases, the spacecraft would be launched as a piggyback.

5.5.3.5 Thermal Control

Although the space environment has not been thoroughly researched, it is accepted that the thermal environment of the spacecraft will need to be capable of sustaining all equipment in an operational state. There may be payloads that require a specific thermal environment (eg. IR and CCD payloads may require low temperatures to operate or for cooling). It is accepted that the spacecraft will work best with a thermal environment equivalent to room temperature (10 to 25° Celsius). More information will need to be gathered on each mission environment before thermal control can be addressed in detail.

5.5.4 Electrical Sub-System

5.5.4.1 Overview

The electrical sub-system is broken into communications, navigation and guidance, power, and on-board data handling.

5.5.4.2 Communications

It is currently under debate whether a high gain antenna is required, since the technology advances from the Galileo mission have enabled sufficient data rates through a low gain antenna, however a 50 cm low gain antenna will probably be required. The antenna will communicate with several ground stations, whose number and location have yet to be determined.

It is expected that around 8 Gbits of solid state memory will be required to collect data between communication phases and provide additional for on-board date handling. Communication to Earth is expected to be in X-band (8 to 12 GHz) and communication from Earth in S-band (2 to 4 GHz). Protocols and networking standards will be adopted from CCSDS. An estimated required downlink rate has been calculated at 0.05 to 0.1 Mbps, however these figures need further investigation to validate.

5.5.4.3 Navigation and Guidance

Investigation will continue into intelligent agents, as have been demonstrated on the Deep Space 1 (DS1) mission. This system uses artificial intelligence software to monitor and report on the spacecraft systems, as well as attempting to solve problems. Health monitoring and onboard diagnosis drastically reduce the need for large operations teams, and reduce costs. Additional research will continue into autonomous navigation, time-share payload planning, and health diagnosis and monitoring systems.

5.5.4.4 Power

Electrical power is supplied to the spacecraft via the solar panels. The solar panels are stowed against the side of the spacecraft for launch, and deployed shortly after attaining LEO. The panels should be mounted on a rotational drive mechanism, enabling them to tilt and rotate to provide the best efficiency. The solar panels will be COTS components and many are available. It is estimated that only 200W will be required when the SEP is not operational, however when thrusting power requirements jump to 1.4 kW. At 200 W, 5 kg of GaAs solar panelling is required and at 1.4 kW, 35 kg is required. Advances in technology may reduce these weights by half over five years. Further investigation will refine these estimations.

Battery technology needs further investigation to accommodate for solar eclipses for the spacecraft. Currently, it is estimated that 450W storage will be sufficient to provide 2.5 hours of power. For NiCd based storage, this equates to 30 kg, however by using NiMH based storage, this can be reduced to 9.4 kg.

5.5.4.5 On-Board Data Handling

While the estimated 8 Gbits of solid-state memory is required to collect data between communication phases, most of the reason it is so large is for on-board data handling (OBDH). Further investigation is required into the capabilities of on-board data handling to select whether attention should be made to navigation, health monitoring, payload planning and operations, or pre-processing of payload data prior to transmission.