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SAR Formation Flying

Annex 9. Industrialization Analysis

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Project Industrialisation Plan for the Garada Formation Flying Synthetic Aperture Radar System

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Executive Summary

This industrialisation plan assesses the Garada tasks that can be performed by Australian industry, the skills that will be developed and the applicability of those skills to future space and earth observation projects. The plan sets out how the Garada project can contribute to the objectives stated in the government's Satellite Utilisation Policy through industry participation. The policy aims are distilled into the following objectives that can be achieved through the Garada project:

a. To increase Australia's depth and breadth of SAR data analysis skills and the application of the data to the Australian community.

b. To increase Australia's small satellite skills to be able to design and develop small satellites.

c. To increase Australia's skills to be able to design and develop instruments for deploying on larger earth observation satellites.

d. To increase the breadth of Australia's skills to be able design, develop and operate the ground segment for Australian owned satellites.

e. To increase Australia's depth and breadth of skills in space engineering.

The opportunities for Australian participation in the Garada space and ground segments are identified and examined. By using the outputs from the Garada Capability Requirements Matrix, that identifies all the capabilities required to perform the Garada program, and the Australian Industry Capability Report, that details the current capabilities of Australian industry, academic and industrial organisations, candidates for Australian industry participation are identified. The current capabilities of Australian industries to undertake this work are assessed and the major conclusions are:

- For the Garada space segment the capabilities relating to the design and manufacture of a spacecraft are considered as occurring in four distinct tiers where:
  - Tier 1 is the major system integrators who sell whole spacecraft and systems.
  - Tier 2 is the companies that provide spacecraft subsystems.
  - Tier 3/4 is the component/parts suppliers to the tier 2 companies.

  There are no tier 1 or tier 2 companies operating in Australia. However, industry, working with the specialist space integration and test capabilities at the Advanced Instrumentation Technology Centre (AITC) in Canberra has capabilities to operate at tier 3/4 in the areas of global navigation systems, communications, antennas, structures, mechanisms, actuators, electronic boards, harnesses, electronic modules and boxes, power supplies, RF components, and systems engineering.

- For the ground segment, the Australian industry capability has much greater strengths in comparison to the space segment and, building on its strengths in satellite communication systems, has the skills to support the design, development and operation of the ground segment required for Garada.

- For the value added processing and SAR application segment, where experts convert the SAR image data and raw data into value added products and apply them to clients' needs. Australia has strong capabilities developed over many years from interpreting and applying optical imagery from space. However the complexity of understanding the imaging process for SAR is much greater than that for optical data and the expertise is not widely available. Programs will be required to bridge the knowledge gap and disseminate the expertise more widely across industry, academia and government.

Surveillance through SAR also brings with it large quantities of data that need to be processed, stored, archived and distributed to users and researchers. Australia has strong expertise in this area as evidenced by the The Research Data Storage Infrastructure Project, Australian National Data Service and Australian Square Kilometre Array Pathfinder programs.

- Australian industry is well placed to support the legal, regulatory, insurance and project management requirements of Garada. Whilst the required project management expertise is widely distributed across industry, the regulatory and insurance knowledge resides in a limited number of individuals but is nonetheless adequate to support a project the size of Garada.

There are gaps in Australia's capabilities and these need to be filled through programs of training and knowledge transfer from specialist overseas companies and space agencies. This report discusses how these capabilities can positively contribute to the Garada project and at the same time progress the achievement of the aims expressed in Australia's Satellite Utilisation Policy. Examples are given of secondment of personnel to the overseas prime contractor; undertaking training such as those offered by local and overseas universities; prime contractor subject matter experts resident on local engineering teams; participation in international earth observation initiatives and government investment in centres of excellence. For each area of participation the skills developed and their applicability to future space and earth observation programs, are described.

Also described is a nominal allocation of work between Australian and Foreign Industry; this is illustrated against a high level work breakdown structure for the Garada mission.

The government's Australian Industry Participation framework, that is based on giving Australian industry full, fair and reasonable opportunity to participate in government projects, is described and discussed. The AIP provides an excellent framework and guidelines for the engagement of the Garada project with Australian industry. A straw man Industry Participation Plan is provided in section 11 that shows how the AIP objectives can be achieved, outlines the actions required and provides a roadmap for implementation.

It is concluded that participation in Garada by Australian industry will provide the fundamental skills for providing complete ground segments for large earth observation satellites as well as nanosats and microsats. This will position industry well for working with the government to implement the upgrades resulting from the National Earth Observation from Space Infrastructure Plan. By actively working with an overseas prime contractor on the Garada spacecraft, which may include seconding Australian engineers into the prime's team, and undertaking work on subsystems, Australia will increase its capability to design and develop nanosats and small microsatellites. Examples of the latter include the proposed: Buccaneer 3U cubesat for Defence, Antarctic Broadband satellites for improved Antarctic communications; and 6U spacecraft for earth observation and scientific purposes.

Application of the SAR processing and interpretation skills obtained through participation in Garada also has ongoing benefits to industry. Applicability of these skills lies not only within the application to diverse solutions within Australia but also to regional neighbours. As our northern neighbours lie in tropical areas with high cloud cover, the cloud penetrating capability of SAR provides more opportunity for the application of earth observation than optical sensors. The use of SAR in these markets represents a strong area for growth for organisations skilled in the interpretation and application of SAR data from Garada and other spacecraft.

1. Scope

This is the Project Industrialisation Plan for the Garada formation flying satellite based Synthetic Aperture Radar (SAR) system. This plan is a deliverable under Garada Work Package 9- Industrialisation Analysis, deliverable TK 9.5 Project Industrialisation Plan.

The Project Industrialisation Plan takes the outputs from the Capability Requirements Matrix (TK9.1) and Australian Industry Capability Report (TK9.2) along with the government's Satellite Utilisation Policy and assesses the Garada tasks that can be performed by Australian industry, the skills that will be developed and the applicability of those skills to future space and earth observation projects. The skill delta that exists between the current skillset in Australia and that required to undertake the tasks is assessed and a roadmap showing how this skill delta can be addressed is provided.

1.1. Work Package Context

The context of this document within WP 9 is illustrated in Figure 1: Work Package 9 Context.

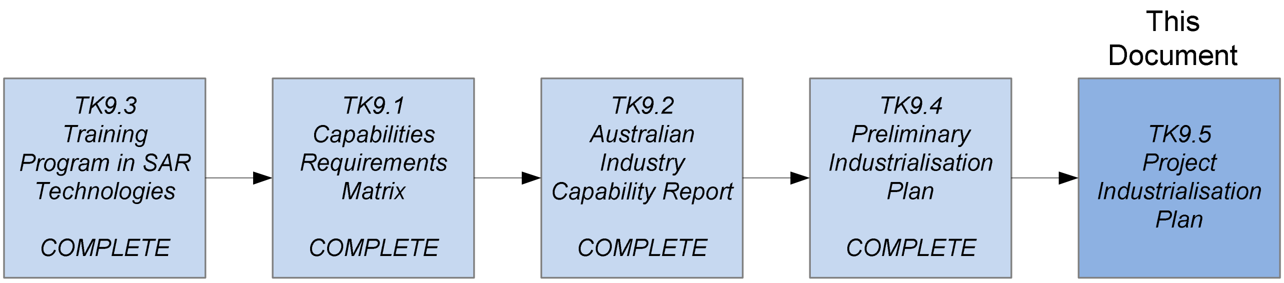

Figure 1: Work Package 9 Context

1.2. Document Purpose

The purpose of this document is to inform stakeholders how the Garada project can be implemented within Australian Industry and the applicability of the skills obtained through this participation to future space and earth observation projects.

2. Referenced Documents, Definitions and Acronyms

2.1. Referenced Documents

Ref	Document Identifier	Title	Rev.	Date
1	2344DT 00006	Australian Industry Capability Report for Garada Formation Flying SAR System	1	21 Dec 12
2	DIISRTE, 12/257	Australia's Satellite Utilisation Policy,		9 Apr 13
3	2344DT 00005	Capability Requirements Matrix for the Garada Formation Flying Synthetic Aperture Radar System	1	31 Mar 12
4	DIISR 11/144	Principles for a National Space Industry Policy		Sep 12

Ref	Document Identifier	Title	Rev.	Date
5	2344DT000 010	Garada Preliminary Ground Segment Architecture.	1	21 Dec
6		"04. 6U CubeSat as the Basis for a Sustainable Australian Space Program - Steven Tsitas[1].pdf" ACSER UNSW		Jun 12
7		http://www.abc.net.au/science/articles/2012/06/06/3519635.htm, Steven Tsitas, ACSER UNSW		06 Jun 12
8		http://antarcticbroadband.com/about/		11
9		Australian Industry Participation National Framework, Commonwealth of Australia.		April 01
10		Australian Industry Participation Plans in Commonwealth Government Procurement, Department of Industry, Innovation, Science, Research and Tertiary Education.	2.0	July 12
11	2012-0224	Robust Imaging from Space, CTG Consulting for DIISRTE	1.1	Aug 12
12		Australia and SAR: A Road Map, John Richards, CRC for Spatial Information		2013
13		TK1.2 Garada SAR Formation Flying Business Case for Implementation	01_01	31 Jan 12
14	2344DT000 05	TK 9.1 Capability Requirements Matrix for the Garada Formation Flying Synthetic Aperture Radar System	1	31 Mar 2012
15	2344DT000 06	TK 9.2 Australian Industry Capability Report for the Garada Formation Flying Synthetic Aperture Radar System	1	21 Dec 2012

2.2. Definitions

Small satellites <500kg are generally defined in terms of the launch mass. The classes of small satellites referred to in this document are defined in Table 1.

Table 1: Satellite Class Definitions

Satellite Class	Mass Range
Pico satellites	< 1kg
Nano satellites	1-10kg
Micro satellites	10-100kg
Mini satellites	100-500kg
Satellites	>500kg

2.3. List of Acronyms

Abbreviation	Expansion
AIP	Australian Industry Participation
AIPP	Australian Industry Participation Plan
AIT	Assembly Integration and Test
AITC	Advanced Instrumentation Technology Centre
ANDS	Australian National Data Service
AOCS	Attitude and Orbital Control System
AR	Acceptance Review
ASKAP	Australian Square Kilometre Array Pathfinder
CDR	Critical Design Review
CRCSI	Cooperative Research Centre for Spatial Information
CRR	Customer Requirements Review
DEM	Digital Elevation Model
DIISRTE	Department of Industry, Innovation, Science, Research and Tertiary Education
ECSS	European Committee for Space Standardisation
EGSE	Electrical Ground Support Equipment
EMI/EMC	Electromagnetic Interference / Electromagnetic Compatibility
EO	Earth Observation
GNSS	Global Navigation Satellite System
HPA	High Power Amplifier
ICN	Industry Capability Network
ILS	Integrated Logistics Support

Abbreviation	Expansion
IP	Intellectual Property
MDR	Mission Definition Review
MGSE	Mechanical Ground Support Equipment
NASA	National Aeronautics and Space Administration
NEOS IP	National Earth Observations from Space Infrastructure Plan
PDR	Preliminary Design Review
QR	Qualification Review
R&D	Research and Development
RDSI	Research Data Storage Infrastructure
RF	Radio Frequency
SAR	Synthetic Aperture Radar
SME	Small / Medium Enterprise
SRR	System Requirements Review
TERN	Terrestrial Ecosystem Research Network
UN	United Nations
V&V	Verification and Validation
WGS	Wideband Global Satcom

3. Background

3.1. Garada Overview

Garada is a proposed Australian led Formation Flying L-Band SAR satellite system that provides SAR imagery and interpreted data to primarily Australian end users for the purposes of soil moisture mapping, forest change detection, flood and disaster monitoring and bistatic research. It is aimed primarily at civilian applications but may also support defence.

The system comprises two identical satellites flying half an orbit apart in a sun synchronous orbit of 630km altitude. The orbit repeat cycle of 6 days results in the whole of Australia being overflown every three days. The main payload is a high resolution L band Synthetic Aperture Radar that has a resolution of 4-11m in range and 7m in azimuth. A secondary payload is a Global Navigation Satellite System (GNSS) receiver designed to receive positioning and timing signals from multiple satellite navigation systems. The satellite is intended to be launched from the, Falcon 9 class launch vehicle. The design is based on Astrium's Snapdragon configuration and TerraSAR-L experience. The primary ground station for receiving the satellite data is located in Antarctica to provide good orbit coverage. The return of the received data to Australia uses the proposed Antarctic broadband link satellite data system (ref 5). A secondary ground station in Tasmania provides additional orbit coverage and redundancy. The mission and payload operations and payload data processing are carried out in an operations centre located in Australia and staffed by Australian personnel.

3.2. Training Program in SAR Technologies

TK9.3 entitled a *Training Program in SAR Technologies* constituted a discrete deliverable in support of Garada Work Package 9 (WP9). It was agreed that the program would take the form of a one-day workshop aimed at imparting knowledge concerning Synthetic Aperture Radar (SAR) techniques, and further raising awareness of the applications and benefits of SAR remote sensing amongst the Australian Earth Observation community spanning Industry, Research and Government.

The following is a summary of the planning and outcome of the SAR Workshop held at UNSW on 7 December 2011. BAE Systems was responsible for coordinating the workshop, with technical support from Astrium and logistic support from UNSW.

3.2.1. Workshop Objectives

The promulgated objectives of the workshop were as follows:

- To provide expert presentations on SAR techniques covering fundamental principles, sensor systems, design considerations, application areas and the benefits of GPS formation-flying
- To provide a forum for the exchange of information between SAR experts, technology providers and end users, particularly requirements relevant to the Garada SAR Formation Flying project
- To facilitate relationships between consortium members and key stakeholders aimed at enhancing the outcomes of the Garada SAR Formation Flying project

3.2.2. Workshop Audience

The workshop was targeted at the following stakeholders:

- SAR Subject Matter Experts (presentation delivery)
- SAR / Earth Observation end users including the Bureau of Meteorology, CSIRO, Geoscience Australia, Defence and other government, research and industry organizations
- Garada consortium members including engineering, research and management personnel
- Other participants including research students

3.2.3. Workshop Program

The workshop program was split into tutorial and application themes covering the morning and afternoon sessions respectively. BAE Systems worked closely with David Hall and Martin Cohen at Astrium, and with Dr Nick Stacy at DSTO in respect to providing SAR subject matter expertise for the tutorial element. This theme was complemented by application-focussed presentations by Geoscience Australia, the Defence Imagery and Geospatial Organisation (DIGO) and UNSW. The workshop culminated in a guided discussion session facilitated by Astrium and supported by DSTO and UNSW panel members. A copy of the publicity flyer containing the workshop program is included in Annex B.

3.2.4. Workshop Outcome

Following distribution of the flyer to a comprehensive mailing list and promotion via the Garada website, the SAR Workshop was successful in attracting ~75 participants from the Industry, Research and Government sectors. This was a significant achievement in respect to bringing together pre-eminent SAR system specialists and principal SAR end users spanning the Civil and Defence communities. In doing so, TK9.3 complemented the broader objectives of WP9 relating to enhancing involvement by Australian Industry and other stakeholders in a future Garada or other SAR mission focussed on meeting national needs.

3.3. Capability Requirements Matrix

Prior to undertaking the industrialisation planning for Garada, an analysis of the capabilities required to undertake all the work was performed. This analysis resulted in publication of the report “TK9.1 Garada Capability Requirements Matrix”, ref 14. A summary of this report is provided in Annex C. This annex lists the high level tasks required to develop, launch and operate the Garada System.

The tasks are structured into a space segment, a launch service segment and a ground segment. Within each segment there is a design and analysis activity to produce the requirements for the next tier and an integration and test activity to “build up” and verify the product from the lower tiers. This process is repeated at each tier, down to the level of granularity necessary to define the required capabilities. Tasks that are likely to involve significant development activities or significant modification of existing products (eg GNSS and SAR) are decomposed to a lower level than those that are likely to be reuse of an existing product with minor modifications, (eg structure, OBDH, AOCS etc).

The required capabilities listed across the top of the matrix are broken down to a level of granularity required to support the identification of a unique or specialist capability required to undertake the Garada project.

Each task is described in terms of the product scope it deals with and the work scope required to undertake the task. By reading across the matrix, the capabilities required to perform the work are identified by an “x” in the relevant column. Each of these capabilities is defined with the capability descriptions being detailed in ref 14.

3.4. Australian Industry Capability

3.4.1. Australian Industry Capability Report

Also providing a key input into this report are the results of the Australian Industry Capability Report for Garada, TK9.2; ref 15, that was undertaken as part of the work package 9 activities. This report surveyed Australian organisations (including government and academia) and assessed their abilities to undertake the capabilities identified in the Garada Capability Requirements Matrix. In fulfilling this, the report provided a snapshot of the capability of Australian organisations to undertake the work related to the Garada mission. Details of the capabilities by individual organisation are provided in ref 15 and are summarised in Table 2.

Table 2: Organisation Capability Summary

Capability Area	Capability	Number of Organisations
Space Segment	Structure	1
	Attitude and Orbital Control	1
	Harness	0
	OBDH	0
	Communications	2
	Thermal Control	0
	Power (solar arrays, storage, and control)	0
	On board computing	1
	Propulsion	6
	Science experiments	7
	Space manufacturing	2
	Telecommunications payloads	3
	Remote sensing payloads	1
	Instruments/sensors/mechanisms/components	9
	Testing	8
	Launch services	0
	Satellite operator	3
Ground Segment	Computer systems and software	20
	Electronics	22
	Ground operations	16
	Ground support/infrastructure	14
	Research and development	40
	Ground Systems engineering	25
	Ground instruments	3
Downstream Services	Navigation services	19
	Broadband services	13
	Broadcasting	11
	Environmental monitoring	16
	Geospatial applications	66
	Meteorology	3
	Narrowband services (voice)	21
Support Services	Consultancy	33
	Financial	0
	Insurance	1
	Legal	10
	Project management	28
	Space education	40
	Space policy	29
Organisation	**Type of Organisation**	**Number of Organisations**
Organisation	Government	29
	Academia	31
	Industry	112
	Association	14

3.4.2. Australian Industry Capability Conclusion

The report concluded that two prime conclusions could be drawn.

- Australia has limited capability in space systems. Participation in the Garada space segment would largely be through specialist research; the supply of parts, components, and minor subsystems for the spacecraft; provision of specialist supporting services; and the provision of personnel to undertake technology transfer by participating in the design and AIT of the spacecraft with the prime contractor.
- Australia has strong capability in ground systems and is capable of priming the ground segment and undertaking the design and development.

In the area of space systems, whilst previously Australia had some capability within commercial industry this has largely disappeared over the last 15 years due to the lack of commercial opportunities and termination of the National Space Program. Currently, Australia has no capabilities as a satellite integrator or satellite subsystem supplier for a spacecraft the size of Garada (3,000-4,000kg.) Australia's space systems capabilities are in the area of component suppliers. Australia has areas of specialist capability that can be applied to spacecraft subsystems but there are few opportunities to do so. The extra specialised production processes and testing required over and above that needed for commercial and military applications are not commercially viable. However, this capability gap is being filled by the Government's investment in the AITC at ANU in Canberra. When completed in 2013, the AITC will provide science and industry with the capability to provide parts, components and small subsystems to the Garada spacecraft. Australia will be able to undertake research, development and manufacture of subsystem components in the specialist areas of communications, antennas, GNSS, propulsion, instrumentation and other areas.

Australia's capabilities in the ground segment are strong. It has capabilities across all of the key areas, the further downstream the capability, the stronger it is. In the upstream area of satellite operation, currently only Optus has this capability. This will be strengthened in the near future by the addition of Newsat and NBN Co who are both procuring satellites that will be operated in this country. Ground station operation and the acquisition and processing of earth observation data has been undertaken by Geoscience Australia and commercial industry for many years. With this background, Australia has the capability to prime the Garada ground segment and undertake the ground systems of ground station, mission operations, payload operations and data processing.

Australia can also make a significant contribution in the specialist services sector. Australia has law firms proficient in international and national space law as well as companies experienced in space insurance brokerage.

4. Project Life Cycle Context

This document provides a plan for Australian Industry to participate in the development, manufacture and operation of the Garada system. In the context of the typical life cycle of space projects, this covers phases 0 to E where the phases are as described below.

The life cycle of space projects is typically divided into 7 phases as follows:

- Phase 0 - Mission analysis/needs identification
- Phase A - Feasibility
- Phase B - Preliminary Definition

- Phase C - Detailed Definition
- Phase D - Qualification and Production
- Phase E - Utilisation
- Phase F - Disposal

Phases 0, A, and B are focused mainly on the elaboration of system functional and technical requirements and identification of system concepts to comply with the mission statement.

Phases C and D comprise all activities to be performed in order to develop and qualify the space and ground segments and their products.

Phase E comprises all activities to be performed in order to launch, commission, utilise, and maintain the orbital elements of the space segment and utilize and maintain the associated ground segment.

Phase F comprises all activities to be performed in order to safely dispose of all products launched into space as well as the ground segment.

Currently, Garada activities are being undertaken that are associated with the project Phase 0 and Phase A scope. This is being carried out under the Australian Space Research Program Funding Agreement ASRP5. These activities comprise the following work packages:

WP1 Space Systems Engineering and Radar Applications

WP2 SAR Solution

WP3 SAR System Analysis

WP4 Bistatic Radar

WP5 Prototype Receiver

WP6 Formation Flying Algorithms

WP7 Orbit Models

WP8 Orbit Control Analysis

WP9 Industrialisation Analysis

WP10 Ground Segment Study.

This Project Industrialisation Plan under WP9 primarily covers the subsequent project phases B, C, D and E.

5. Objectives

This industrialisation plan is written with the aim of the Garada project contributing to the following objectives derived from references 2 and 13.

a. To increase Australia's depth and breadth of SAR data analysis skills and the application of the data to the Australian community.

b. To meet applicable objectives in Australia's Satellite Utilisation Policy. (ref 2 and sections 6 and 10.

c. To increase Australia's small satellite skills to be able to design and develop small satellites.

d. To increase Australia's skills to be able to design and develop instruments for deploying on larger earth observation satellites.

e. To increase the breadth of Australia's skills to be able design, develop and operate the ground segment for Australian owned satellites.

f. To increase Australia's depth and breadth of skills in space engineering.

6. Space Policy Considerations

Australia aims to achieve ongoing cost effective access to the space capabilities on which it relies. To this end, the government has produced a policy, known as Australia's Satellite Utilisation Policy (ref 2), to express Australia's space objectives. This policy follows on from the Principles for a National Space Industry Policy published in 2011 (Ref 4). The Satellite Utilisation Policy was issued by the Government on 9th April 2013. It expands on the principles by providing specific statements of how each principle will be implemented. In the policy, the government has not committed Australia to human spaceflight, domestic launch capabilities or exploration of other planets. Instead it focuses on the space capabilities that Australia depends on. Specifically earth observation, satellite communications and position, navigation and timing. Australia's participation in the Garada project needs to align with the aims expressed in the policy to contribute to Australia's long term future in space.

The policy aims relevant to Garada that are used to guide this plan are:

- Prioritise research focused on earth observations from space, satellite communication and positioning, navigation and timing. (Principle 1)
- Build and retain high quality Australian space expertise. (Principle 6)
- Ensure Australia has the infrastructure, capabilities and skills to access, process, store, integrate, use and distribute the data and information from space systems. (Principle 2)
- Develop Australian systems, sensors, hosted payloads or *(small)* satellites. (Principle 2)
- Facilitate academic, inter-government and industry exchanges with appropriate international partners. (Principle 6)

There are areas where it is strategically beneficial for Australian Industry to be involved. Participation in the development of sensors, instruments, payloads and the undertaking of satellite operation and data processing is of strategic benefit to industry. Participation in the development of spacecraft platforms and platform subsystems that can be readily purchased from overseas suppliers is not of long term interest to industry. A stated strategic aim of the Australian Government is to manage the risks of over dependence on international systems by developing Australian systems, sensors and hosted payloads. Correspondingly, the most beneficial areas for industry participation in the Garada project are those relating to the spacecraft payload and sensor development, ground segment development and operation, and the downstream, value added interpretation and application of the SAR data.

7. Garada in Context of the Australian SAR Reports

Two reports covering the future use of SAR imaging in Australia have been recently published by the CRC for Spatial Information (CRCSI). “Robust Imaging from Space” by CTG Consulting (ref 11), and “Australia and SAR: A Road Map” (ref 12) by John Richards. The former assesses the need for the development and operation of a space based SAR imaging capability in Australia and identifies many opportunities for improvement in Australian SAR capabilities. The latter report builds on the former and recommends a road map for an incremental cost effective strategy for Australia’s continued access to future SAR imagery. The roadmap report (ref 12) describes the significant benefits the all weather, wide area imaging capability of SAR spacecraft bring to a wide range of applications. To access this data, Australia currently relies on the investments in SAR systems by other nations. To continue to access SAR data, Australia needs to determine whether it can rely with confidence on overseas data providers for applications of national interest or whether it needs to secure future access by contributing to space and ground segment hardware. The roadmap report discusses these options and describes the multiple choices that are available to Australia to continue as a user of SAR data. The analysis is conducted across the three principal segments in the SAR value chain of space segment, ground segment and the value adding segment that converts and applies the SAR data to existing and innovative applications for clients. These options and their advantages and disadvantages are summarised in Table 3 which is taken from the roadmap report.

The roadmap report concludes that the best option for Australia is to proceed with Australian equity in another nation’s SAR spacecraft program, share the ground segment with the other nation and develop a skilled Australian SAR workforce that is able to interpret the SAR data and apply it to the multiple needs of Australian users. Of the options available, this combination comes at a lower cost and risk and allows the development of Australian expertise, particularly in the value added segment. These options are highlighted in yellow in Table 3 as the recommendations from the Road Map report. The report concludes with a transition plan for moving from the current Australian skill base in SAR expertise to that required to support the recommended options.

In contrast, Garada is a proposal for Australia to own, or have significant equity in, a specialised SAR spacecraft that is optimised to Australia’s needs, (ref 13). Optimised in this context is in relation to the orbit to give full coverage of Australia with a 3 day revisit rate, and SAR performance to provide soil moisture measurements to the level of fidelity required for Australian farm management and strategic resource management. These choices are highlighted in Table 3 in green. This set of choices also requires a transition plan to move from the current Australian skill base to one that is able to support Garada and future programs.

This document describes the realistic participation Australian industry could take in the Garada project, the longer term benefits to industry and Australia, and the roadmap to achievement.

Table 3: Participation Choices Available (from Ref 12)

ID	Choice	Principal Advantages	Principal Disadvantages	Notes
Space Segment				
SS1	Purchase of data as required	Lowest cost	Supply continuity not guaranteed, pricing not guaranteed	
SS2	Australian equity in another nation's future program	Moderate cost, less compromise, may influence later specifications	Lead time may be unacceptable	Recommended choice in "*Australia and SAR: A Road Map*"
SS3	Australian equity in another nation's current program	Moderate cost, compromise, acceptable lead time	Accept current specifications	
SS4	An Australian SAR on another nation's spacecraft	Optimised instrument	Moderately expensive, high risk, local skills needed, long lead time	
SS5	An Australian spacecraft or cluster	Total design control	Expensive, high risk, local skills needed, long lead time	Garada solution
Ground Segment				
GS1	Overseas ground segment	Lowest cost	Minimal control over acquisitions	
GS2	Shared ground segment	Moderate cost, compromise	May not be optimal	Recommended choice in "*Australia and SAR: A Road Map*"
GS3	Dedicated Australian ground segment	Total design control	Expensive, high risk, local skills needed, long lead time	Garada solution
Value Added Segment				
VAS1	Source expertise from overseas on fee for service	Low cost	No Australian skills development and thus no value added markets	
VAS2	Establish single expert agency	Skilled Australians, best funded	High risk, since investment in key people not spread	Recommended choice in "*Australia and SAR: A Road Map*"
VAS3	Establish several expert agencies	Skilled Australians, risk spread	Resources are spread; may offset by networking	Garada solution Recommended choice in "*Australia and SAR: A Road Map*"

8. Australian Industry Participation in Garada

8.1. Opportunities for Australian Industry Participation

The capabilities required to undertake the Garada project are contained in the Garada Capability Requirements Matrix (ref 3). This document lists the high level tasks required to develop, launch and operate the Garada System. The tasks are structured into a space segment and a ground segment. The space segment consists of a spacecraft, launch services and ground support equipment. The ground segment incorporates the ground station, the satellite monitoring and control facility, data processing and distribution. Within each segment there are design and analysis activities to produce the requirements for the next lower subsystem and an integration and test activity to "build up" and verify the product from the lower subsystems. This process is repeated at each level, down to the degree of granularity necessary to define the required capabilities. For each task, the capabilities required to undertake it are defined.

Having identified all of the capabilities required to build and operate the Garada system, the current indigenous capabilities of Australian industries to undertake this work were assessed in the Australian Industry Capability Report (ref 1). This report surveys Australian industries and assesses their capabilities with respect to the Garada project. The major conclusions of this report are:

- For the Garada space segment the capabilities relating to the design and manufacture of a spacecraft are considered as occurring in four distinct tiers where:
  - Tier 1 is the major system integrators who sell whole spacecraft and systems.
  - Tier 2 is the companies that provide spacecraft subsystems.
  - Tier 3/4 is the component/parts suppliers to the tier 2 companies.

  The report recognises that there are no tier 1 or tier 2 companies operating in Australia. It concludes that industry, working with the specialist space integration and test capabilities at the Advanced Instrumentation Technology Centre (AITC) in Canberra has capabilities to operate at tier 3/4 in the areas of global navigation systems, communications, antennas, structures, mechanisms, actuators, electronic boards, harnesses, electronic modules and boxes, power supplies, RF components, and systems engineering.

- For the ground segment, the report concludes that Australian industry capability has much greater strengths in comparison to the space segment and, building on its strengths in satellite communication systems, has the skills to support the design, development and operation of the ground segment required for Garada.

- For the value added processing and SAR application segment, where experts convert the SAR image data and raw data into value added products and apply them to clients' needs. Australia has strong capabilities developed over many years from interpreting and applying optical imagery from space. However the complexity of understanding the imaging process for SAR is much greater than that for optical data (ref 12) and the expertise is not widely available. Programs will be required to bridge the knowledge gap and disseminate the expertise more widely across industry, academia and government.

- Australian industry is well placed to support the legal, regulatory, insurance and project management requirements of Garada. Whilst the required project management expertise is widely distributed across industry, the regulatory and insurance knowledge resides in a limited number of individuals but is nonetheless adequate to support a project the size of Garada.

There are gaps in Australia's capabilities and these need to be filled through programs of training and knowledge transfer from specialist overseas companies and space agencies. The next section discusses how these capabilities can positively contribute to the Garada project and at the same time progress the achievement of the aims expressed in Australia's Satellite Utilisation Policy. Also described is a nominal allocation of work between Australian and Foreign Industry; this is further illustrated in Figure 2, that follows section 8.1, against a high level work breakdown structure for the Garada mission.

8.1.1. Garada Space Segment

8.1.1.1. Spacecraft

Owing to the size of the SAR required to meet the Garada prime objectives, Garada will be a relatively large, 3,000kg spacecraft. As there are no tier 1 or tier 2 companies operating in Australia at this level (ref 1), the project will need to be primed by an overseas company. To minimise the risk and development cost, the prime will base the spacecraft on an existing platform. However, there will still be significant development required for the SAR and Global Navigation Satellite Subsystem (GNSS) payloads and the integration of the payloads and platform. There are no Australian companies that have developed and delivered space borne SAR systems so this task will likely be undertaken by an appropriately experienced overseas company with a successful track record in space borne SAR, most likely the spacecraft prime contractor. The SAR itself is unique and although it will likely be based on existing proven systems, it will require bespoke development. Candidate development items that match Australia's indigenous capabilities include the SAR antenna panels, distributed power amplifiers and radiation hardened RF chips.

The major platform systems, including the harness, structure, AOCS, power and thermal control are likely to be existing, proven products that require little development to meet Garada requirements. There is correspondingly little role for Australian development activities and industry participation for these subsystems and no strategic imperative to be involved.

An exception to this may be the communications system. If the design analysis confirms Ka band as the waveband of choice for the spacecraft high speed downlink, there may be a reasonable amount of development required. The Ka band is not currently used on many spacecraft. Most existing earth observation spacecraft use the lower frequency X band, so the availability of existing mature communications subsystems for Garada is likely to be limited. Potential development items that match Australian capabilities in this area include the antennas, antenna feeds and RF power amplifiers. Development of these items is aligned with the main aims for Garada as the knowledge and experience gained from undertaking these activities are directly relevant to producing communications subsystems for small satellites.

Build to print activities where Australian industry builds and tests a spacecraft item based on a proven set of drawings, processes and procedures supplied by the prime contractor are not seen as a viable activity for Australian industry to undertake. Build to print was undertaken in the 90s for Australia's communications satellites and included the manufacture of harnesses, electronic boxes, mechanisms and laser retro-reflectors. In the case of Garada, the manufacture of a one off in an unproven Australian facility increases the risk and cost to the project and offers little return to Australian industry. It also does not fulfil the aims in the Satellite Utilisation Policy.

The other spacecraft payload, the GNSS, is an Australian designed navigation receiver that has been developed to receive the GPS L1, L5 and the future Galileo E1 and E5 navigation signals. The use of carrier phase measurements allows higher accuracy positioning information to be obtained compared to conventional techniques. The research and development of this receiver is being undertaken by the University of New South Wales and the manufacture, qualification and test are candidates to be performed by industry as part of Project Garada.

8.1.1.2. Launch

The launch of the Garada spacecraft and insertion into sun synchronous orbit will be undertaken by an existing launch services provider. These companies specialise in launching spacecraft. They undertake the construction of the carrier rocket, assembly and stacking, payload integration and the conduct of the launch itself. The launch services provider is usually contracted by the spacecraft prime contractor and works closely with them to integrate the spacecraft to the launcher. There is little opportunity for Australian industry involvement in the launch itself, but Australian industry can be involved in the orbit sequencing, testing and commissioning of the spacecraft immediately after launch during the Launch and Early Orbit Phase of operations.

8.1.1.3. Ground Support Equipment

Ground Support Equipment consists of both Electrical Ground Support Equipment (EGSE) and Mechanical Ground Support Equipment (MGSE). EGSE is used to integrate and test the electrical functions of individual spacecraft subsystems prior to integration and the complete spacecraft during the system integration and test phase. MGSE includes jigs, fixtures, and packaging and handling equipment to support the assembly, integration and test of the spacecraft and its shipping to the launch service provider. Some E/MGSE will exist within the spacecraft prime and other items can be procured off the shelf from specialist providers. Nevertheless, new and modified E/MGSE will be required for Garada to support the newly developed items and these are good candidates to be undertaken by Australian industry. As the ground support equipment does not fly in space it is not required to be built to the same quality standards and processes. This matches the capability of many Australian industries.

8.1.2. Garada Ground Segment

Australia has extensive experience in all facets of the required ground segment, from the design and installation of ground stations, satellite control and monitoring facilities, to the processing of the payload data. Examples of these capabilities include Australian industry undertaking the design and installation of the 9m Earth observation satellite receiving station at Shoal Bay, Darwin as well as satellite transmit receive stations for the military including the 16m X/Ka band WGS teleport at Geraldton WA, land mobile and ship mobile satcom stations for the Australian Army and Navy. Many teleports for civil communications have also been installed by Optus, Telstra, Newsat and NBNCo.

The Optus satellite communications facility at Belrose, Sydney has housed the operations centre for Optus satellite services since 1985 and controls their current satellite fleet as well as providing launch support to foreign satellite operators. It provides satellite and earth station monitoring, launch support, and telemetry tracking and command maintenance. With these skills and the strong multidiscipline project management, hardware and software capabilities residing in the Australian defence and commercial industries, Australian industry is capable of priming the ground segment and undertaking the design, development, installation and commissioning of all ground subsystems.

Surveillance through SAR also brings with it large quantities of data that need to be processed, stored, archived and distributed to users and researchers. The quantities of data produced by Garada are described in reference 5 and will require data systems capable of handling petabytes of data. Whilst these are large compared to optical data, Australia has the experience and capability to develop the infrastructure required. Relevant capabilities that lead to this conclusion include:

a. The Research Data Storage Infrastructure Project (RDSI) is developing data infrastructures and services to handle the large volumes of research data generated in Australia and improve the availability of accessibility of the data to researchers.

b. The Australian National Data Service (ANDS) is providing a framework for the planning, collection, analysis, and archiving of large amounts of data. The processes, procedures, metadata tools and training produced by the ANDS are directly relevant to the management and handling of Garada data.

c. The Terrestrial Ecosystem Research Network (TERN) developed in Australia is a national data infrastructure providing the capability for scientists to collect, store, share and integrate large volumes of ecosystems data across disciplines.

d. The Australian Square Kilometre Array Pathfinder (ASKAP) project is developing computing, storage and distribution systems for handling the enormous data rates and quantities that will be produced by the operational array. The Pawsey supercomputing centre is the largest processing and storage facility in Australia and far exceeds the capabilities required for Garada.

8.1.3. Value Added Services

The Australian Industry Capability Report for Garada (ref 1) surveys Australian organisational capabilities across the space, ground, support and downstream value added segments. By far the strongest indigenous capability exists within the geospatial applications sector in value added services. A highly skilled workforce exists across industry, academia and government for the processing and innovative application of optical earth observation imagery. However, as described above, SAR image analysis skills are not so abundant. To justify the high initial investment in a SAR space and ground segment, Australia needs a range of SAR image experts disseminated throughout the user and application community to enable the wealth of information available from SAR to be applied to Australia's national interests. As described in ref 12 this can be achieved through a phased and tiered program of investment in R&D centres to build expertise, cooperative and exchange programs to transfer relevant SAR processing and application skills from overseas to Australia, explore future benefits of SAR and derived products to Australia, and provide assistance for small businesses to establish value added agencies for SAR and integrate SAR data with their existing expertise in optical data.

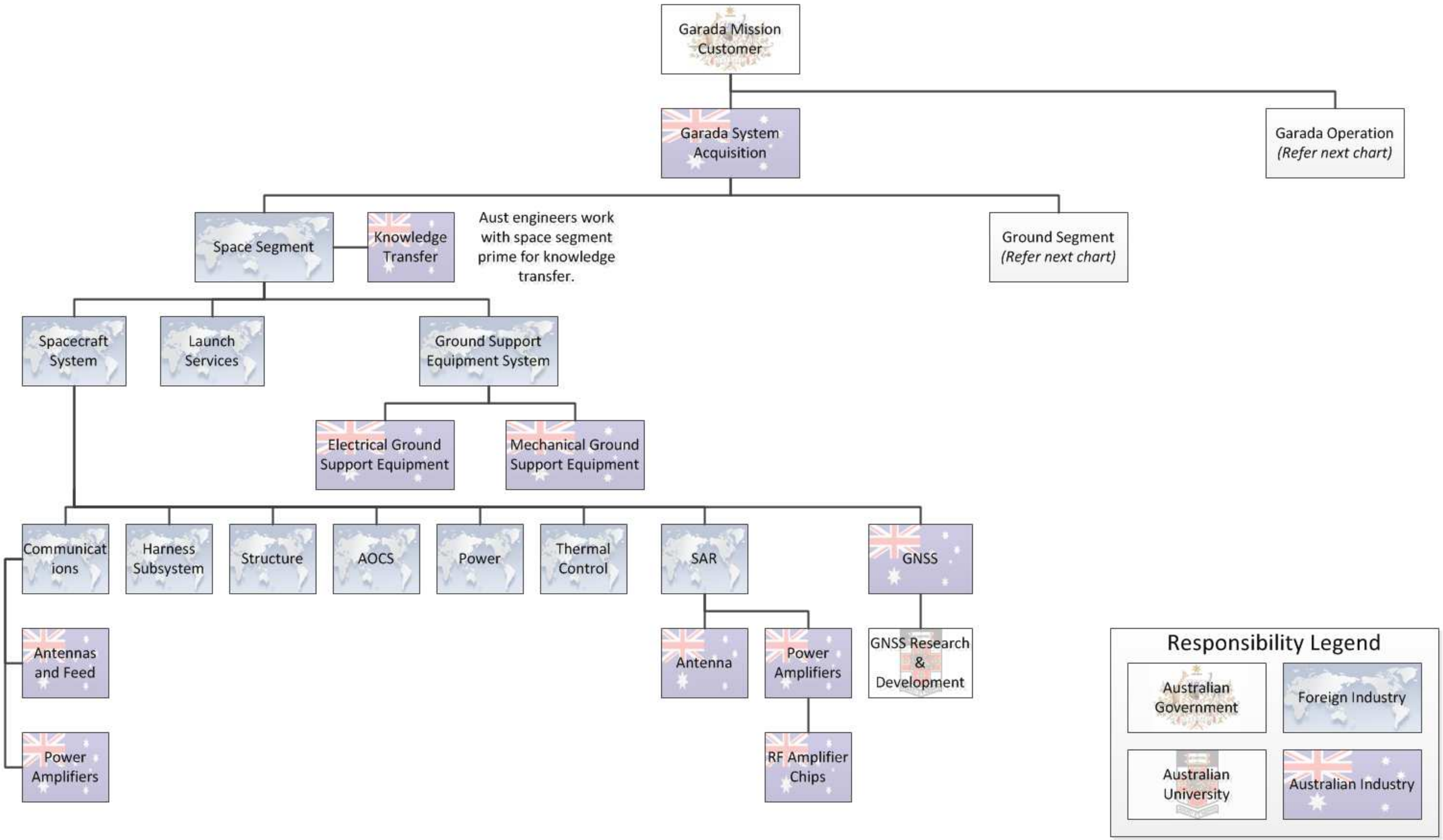

Figure 2: Garada Australian Industry Involvement- Space Segment

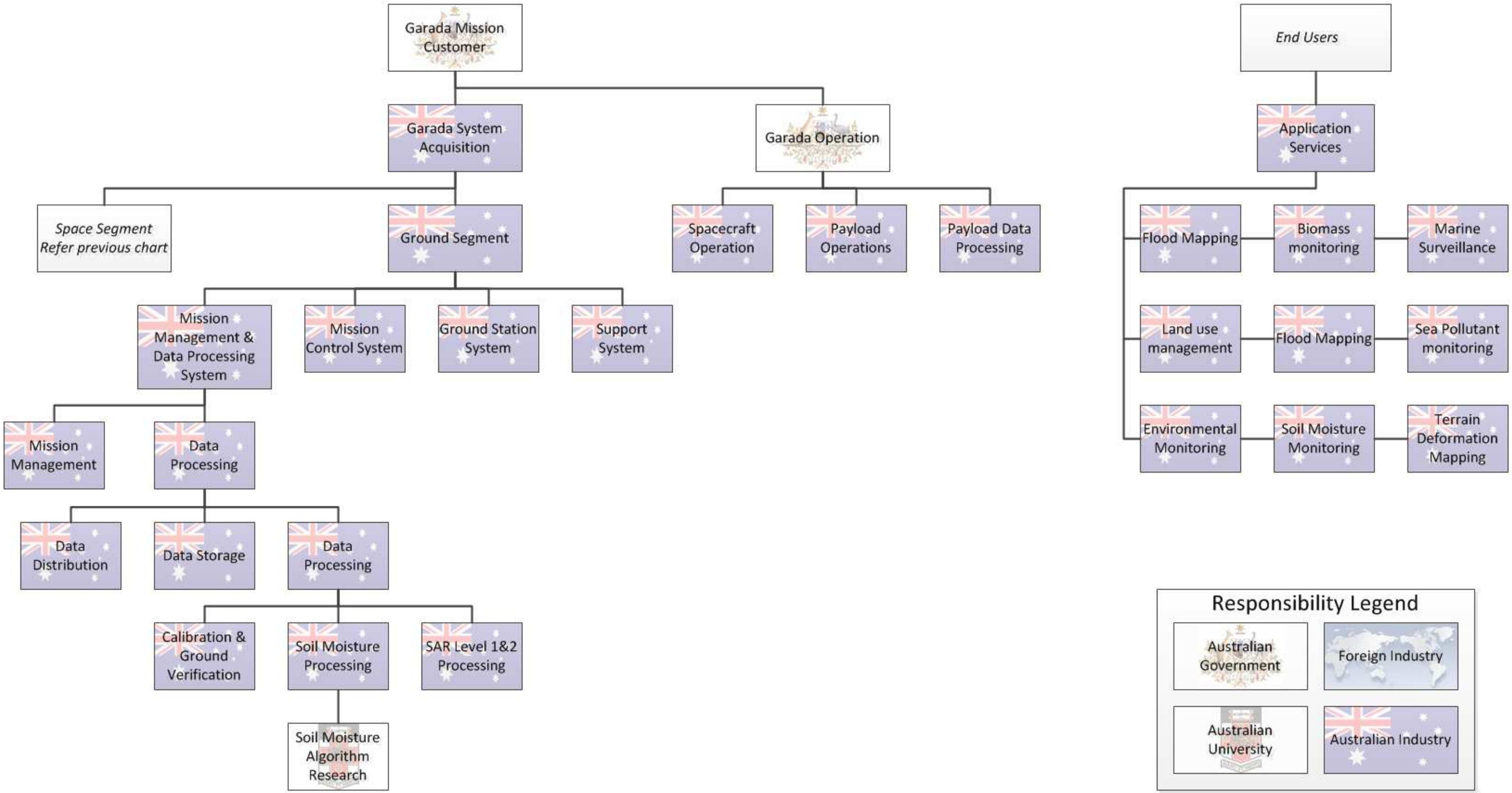

Figure 3: Garada Australian Industry Involvement- Ground Segment and Applications

8.2. Australian Skills Developed and Applicability to Future Programs

For each of the areas identified in section 8.2 as candidates for Australian industry participation, the skills developed and their applicability to future space and earth observation programs, as identified in the Satellite Utilisation Policy, are described in Table 4. Participation in Garada by Australian industry will provide the fundamental skills for providing complete ground segments for large earth observation satellites as well as nanosats and microsats. This will position industry well for working with the government to implement the upgraces resulting from the National Earth Observation from Space Infrastructure Plan (NEOS-IP)[1]. By actively working with a Tier 1 prime on the Garada spacecraft, which may include seconding Australian engineers into the prime's team, and undertaking tier 3 work on subsystems, Australia will increase its capability to undertake tier 1 and tier 2 roles on nanosats and small microsatellites. Examples of the latter include the proposed: Buccaneer 3U cubesat for Defence, Antarctic Broadband satellites for improved Antarctic communications (Ref 8); and 6U spacecraft for earth observation and scientific purposes (Refs 6 and 7).

Future applicability of skills in the use and interpretation of SAR imagery lies not only within the application to diverse solutions within Australia but also to regional neighbours. As our immediate neighbours lie in tropical areas with high cloud cover, the cloud penetrating capability of SAR provides more accessibility to space imaging than through conventional optical means. The application of SAR to resource management requires skills that are in excess of those required for optical image interpretation. The use of SAR in these markets is not as extensive as optical imagery and represents a strong area for growth for organisations skilled in the interpretation and application of SAR data.

[1] NEOS-IP has been developed by Geoscience Australia and the Bureau of Meteorology but has not yet been released to industry.

Table 4: Australian Involvement and Skills Applicability

Task	Australian Industry Involvement	Australian Skills Developed	Applicability of Skills
Risk and Safety Assessment	Safety assessments and risk assessments during AIT, launch, in orbit and continuity of operations	Risk and safety assessments applicable to earth observation satellites.	Risk and safety assessments for future indigenous space programs
Legal	Advice on Australian legislation, UN space charters, international space law, technology transfer, export controls, launch liabilities.	Application of existing skills and knowledge.	Risk and safety assessments for future indigenous space programs
Insurance	Space insurance brokerage	Application of existing skills and knowledge.	Insurance for future indigenous space programs.
Garada Systems Engineering	Australian engineers participate with the engineering team at the overseas prime contractor. Knowledge is gained in the requirements, standards, processes, and methods required for design, manufacture, integration and test of payloads, subsystems and spacecraft.	Spacecraft and tier 2/3 subsystem design, manufacture, integrate and test. SAR development and integration, processes, procedures and standards for spacecraft manufacture.	Skills to undertake tier 1 and tier 2 design, manufacture and test eg: • Instruments for large spacecraft, • Complete nanosats and • Complete microsats.
Spacecraft communications subsystem	Design, development, qualification of Ka band antennas, feeds, power amplifiers.	Ka antenna design, space materials and structures, high reliability, radiation hardened electronics.	Communication and telemetry subsystems of nanosats and microsats.
SAR Antenna Structure	Design, development and qualification of L band antenna structure. Work hand in hand with antenna designers.	Stiff, lightweight structures for spacecraft. Materials and mechanisms.	Deployable structures for nanosats.
SAR Antenna RF Radiator	Work with SAR prime contractor to undertake L band antenna array design, manufacture and test.	Deployable SAR antennas with integrated RF drives.	Increased depth in existing skills for antenna design for aircraft mounted SAR.
SAR Antenna Drive electronics	Design, development, qualification of HPA chips and RF amplifier.	RF space electronics design, manufacture and test for space based communication systems.	Communication and telemetry subsystems of nanosats and microsats.

Task	Australian Industry Involvement	Australian Skills Developed	Applicability of Skills
GNSS Systems Engineering	Academia undertakes: Requirement analysis and system design Industry undertakes: Supporting engineering reviews	Integrated multisystem satellite navigation subsystems. Front end and processing algorithms.	Applicable to the systems engineering of instruments for nanosats and microsats.
GNSS Antenna	Academia undertakes: Research and design. Industry undertakes: Manufacture and test	Design, manufacture and test of multi GNSS antennas for spacecraft.	Applicable to the orbital control system of nanosats and microsats.
GNSS Receiver	Academia undertakes: Research and design. Industry undertakes: Manufacture and test	RF and processing design, manufacture and test of electronic boards and multi GNSS for spacecraft. Multi GNSS processing algorithms.	Applicable to the orbital control system of nanosats and microsats.
GNSS Integration and Test	Industry: integrate and test	Space electronics integration, qualification and test.	The design, manufacture and test of complete nanosats and microsats and instruments for large spacecraft.
Ground Support Equipment for Spacecraft	Spacecraft overseas prime will specify the requirements. Australian industry will undertake the design, development, manufacture and test. Industry works with spacecraft prime contractor to integrate the ground support equipment with the spacecraft.	Electronic and mechanical equipment design, manufacture and test. Knowledge of the special requirements and processes for interfacing EGSE and MGSE with spacecraft.	The design, manufacture and test of support equipment for nanosats, microsats and instruments for large spacecraft.
Ground Segment Systems Engineering	Analyse, synthesise solutions, undertake trades, decompose and allocate requirements to lower level items. Design physical and functional architectures and characteristics. Verify that the ground segment conforms to the requirements.	Systems engineering skills in EO satellite ground segment analysis and synthesis	The system design of ground segments for future EO satellites.

Task	Australian Industry Involvement	Australian Skills Developed	Applicability of Skills
Ground Segment Mission Management and Data Processing Subsystem	Design, development and commissioning of facilities, hardware and software to undertake the SAR Data Processing, SAR image interpretation, archiving, processing of customer requests, scheduling & prioritising of imaging activities. including R&D into soil moisture measurement, SAR calibration, flood outlines, land use, Digital Elevation Model (DEM) generation, and maritime applications.	Skills in processing raw SAR data to end products including path image, single look complex, and map image. Interpreting SAR data to produce end products including flood boundaries, oil slicks, forestry areas, land use states. Data archiving and distribution, customer interfacing.	Processing of raw data from EO SAR sensors, interpretation of SAR data to meet end user needs.
Ground Segment Mission Control Subsystem	Design, development and commissioning of facilities, hardware and software to undertake control of the Garada mission including attitude and orbital control, spacecraft commanding and control, telemetry analysis and reaction, and SAR control functions.	Skills in satellite monitoring, and control software and hardware, mission operations rules, plans and procedures, control centre facilities. Integration of mission and payload control software products. Skills in analysis, planning, scheduling and control of SAR payloads.	Design of monitoring and control systems for future Australian EO satellites.
Ground Segment Ground Station Subsystem	Design, development and commissioning of facilities, hardware and software to undertake the RF transmission and reception to/from the space segment. Includes telemetry, command, control and data links, ranging, and timing.	Skills in telemetry and tele-command subsystems, antenna, satellite communications, ranging, timing, and station monitor and control subsystems.	Design and development of ground stations for earth observation satellites.
Ground Segment Support Subsystem	Generation and provision of the test equipment, spares, operating and maintenance manuals and procedures, and operator and maintainer training required to support the ground segment.	EO Satellite operations training and maintenance training and training aids.	Support of satellite ground stations, computing equipment and software for satellite monitoring and control and payload data processing.
Ground Segment Integration and Verification testing	Integration and test of the ground segment including interfacing with the space segment.	Integration of ground subsystems, ground systems testing. Launch support, on orbit support.	Integration and verification of ground systems for earth observation satellites including nanosats and microsats.

Task	Australian Industry Involvement	Australian Skills Developed	Applicability of Skills
Project Management	Integration and test of the ground segment including interfacing with the space segment.	Planning, cost, schedule, risk and configuration management of ground systems projects including interfacing with overseas primes.	Project management of satellite and space ground segment projects.
Mission Operations	Mission analysis, simulation, planning, scheduling, monitoring and control, performance analysis.	Mission planning and operation of earth observation satellites and payloads.	Mission planning and operation of nanosats and microsats.
Payload operations	SAR operations analysis, planning, scheduling, calibration and control.	Analysis, planning, scheduling, calibration and control of space borne SAR payloads.	Analysis, planning, scheduling and control of Australian hosted payloads on overseas spacecraft.
Payload Data Operations	Payload data reception, processing, archiving and distribution of first order data products.	Increases the existing skills in reception, processing, archiving, and distribution of SAR data. SAR application specialists, wide availability of SAR expertise within industry, govt and academia.	Reception, processing, archiving, and distribution of SAR data from existing and future foreign owned satellites. Innovative application of SAR data to resolve customer problems.
Value Added Processing	Analysis of customer needs, algorithm development and refinement, data processing, data distribution, customer interfacing, user applications and services.	Fusing of SAR and optical data. Generation of application specific products including soil moisture measurements, disaster management, biomass estimation, sea pollution monitoring.	Innovative application of SAR to Australian customers' needs. Application of SAR to neighbouring countries.
Integrated Logistics Support (ILS)	System maintenance and obsolescence management, performance analysis and reporting, software development and validation.	Application of existing Australian ILS skills, little development of new skills required.	ILS support of Australian owned nanosats and microsats.

8.3. Capabilities Required for the Tasks

The candidates for Australian industry involvement in the development, production and ongoing operation of Garada are described in Table 4. The Australian industry involvement, the skills developed and the applicability of the skills to future Australian space projects is detailed for each candidate task. The core capabilities to undertake many of the tasks already exist within Australian industry and require none or a minimal learning curve as a precondition to undertaking the task. Some tasks, particularly those in the space segment, require skills that are not currently possessed by Australian industry, or exist in tiny pockets scattered throughout the aerospace industry. From the Australian Industry Capability Report (ref 1), there is a skill delta between that which is required to undertake some tasks and that which currently exists. This basic delta needs to be filled prior to Australian industry taking on the task and building on the skill to establish a core capability that can contribute to the indigenous development of scientific payloads and small Australian satellites.

Australia had strong skills in SAR processing and interpretation in the 90’s, primarily driven by the ready accessibility of data from the ERS1 and ERS2 satellites for which Australia had an indigenous receiving station and a small financial investment in the spacecraft. Australian industry also designed and manufactured a Fast Delivery Processor for the SAR data from ERS1 and ERS2. Most of these skills have dissipated or not kept pace with recent developments (ref 12). Australia’s earth observation skills, particularly outside of government agencies and research institutions, primarily focus on the analysis and application of satellite optical imagery. SAR image analysis is more complex; the analyser needs a strong understanding of the scattering behaviour of the radar beam on the Earth’s surface which is a function of the surface materials, wavelength, look angle and other characteristics of the beam. SAR data is used in a few state-wide monitoring programs but is not used operationally elsewhere (ref 11). There is a skill delta not only in the processing and analysis of SAR imagery but also in the application of the technology to Australia’s national priorities; eg soil moisture measurement from space is a technology that is in its infancy and requires research and development to produce the algorithms suitable for Australia and dissemination of the skills into the broader EO and agricultural communities.

Table 5 lists the Australian skill delta for each of the tasks in Table 4 and, where a delta exists, describes means by which the difference can be addressed. This can be through secondment of personnel to the overseas prime contractor; undertaking training such as those offered by local (eg satellite systems engineering at UNSW) and overseas universities; prime contractor subject matter experts resident on local engineering teams; participation in international earth observation initiatives and government investment in centres of excellence.

Table 5: Australian Skill Deltas

Task	Australian Industry Involvement	Australian skill delta	Means of addressing
Risk and Safety Assessment	Safety assessments and risk assessments during AIT, launch, in orbit and continuity of operations	None	
Legal	Advice on Australian legislation, UN space charters, international space law, technology transfer, export controls, launch liabilities.	None	
Insurance	Space insurance brokerage	None	
Garada Systems Engineering	Participation in spacecraft system design with aim of acquiring the skills to undertake the system design on smaller spacecraft.	Spacecraft systems engineering.	Australian engineers participate with the engineering team at the overseas prime contractor. Knowledge is gained in the requirements, standards, processes, and methods required for design, manufacture, integration and test of payloads, subsystems and spacecraft.
Spacecraft communications subsystem	Design, development, qualification of Ka band antennas, feeds, power amplifiers.	Space materials, parts and processes, space environment.	Work with spacecraft prime contractor to undertake training in space materials, parts, structures and processes. Undertake external training courses such as those offered by Surrey University and University of South Hampton.
SAR Antenna Structure	Design, development and qualification of L band antenna structure for spacecraft. Work hand in hand with antenna designers.	Space materials, parts and processes, structures, space environment.	Work with SAR prime contractor to undertake training in space materials, parts, structures and processes. Undertake external training courses such as those offered by Surrey University and University of South Hampton.
SAR Antenna RF Radiator	L band antenna array design, manufacture and test.	Space materials, parts and processes, space environment.	Work with SAR prime contractor to undertake training in space materials, parts and processes. Undertake external training courses such as those offered by Surrey University and University of South Hampton.

Task	Australian Industry Involvement	Australian skill delta	Means of addressing
SAR Antenna Drive electronics	Design, development, qualification of HPA chips and RF amplifier.	Space materials, parts and processes, space environment.	Work with spacecraft prime contractor to undertake training in space materials, parts and processes. Undertake external training courses such as those offered by Surrey University and University of South Hampton.
GNSS Systems Engineering	Academia undertakes: Requirement analysis and system design Industry undertakes: Supporting engineering reviews	None	
GNSS Antenna	Academia undertakes: Research and design. Industry undertakes: Manufacture and test	Manufacture of space qualified hardware.	Secondments of engineers and manufacturing personnel to spacecraft prime contractor. Training in space manufacturing quality and accreditation processes through ESA or other space agencies.
GNSS Receiver	Academia undertakes: Research and design. Industry undertakes: Manufacture and test	Manufacture of space qualified hardware.	Secondments of engineers and manufacturing personnel to spacecraft prime contractor. Training in space manufacturing quality and accreditation processes through ESA or other space agencies.
GNSS Integration and Test	Industry: integrate and test	None	
Ground Support Equipment for Spacecraft	Spacecraft overseas prime will specify the requirements. Australian industry will undertake the design, development, manufacture and test. Industry works with spacecraft prime contractor to interface the ground support equipment with the spacecraft.	None	
Ground Segment Systems Engineering	Analyse, synthesise solutions, undertake trades, decompose and allocate requirements to lower level items. Design physical and functional architectures and characteristics. Verify that the ground segment conforms to the requirements.	None	

Task	Australian Industry Involvement	Australian skill delta	Means of addressing
Ground Segment Mission Management and Data Processing Subsystem	Design, development and commissioning of facilities, hardware and software to undertake the SAR Data Processing, SAR image interpretation, archiving, processing of customer requests, scheduling & prioritising of imaging activities. including R&D into soil moisture measurement, SAR calibration, flood outlines, land use, Digital Elevation Model (DEM) generation, and maritime applications.	None	
Ground Segment Mission Control Subsystem	Design, development and commissioning of facilities, hardware and software to undertake control of the Garada mission including attitude and orbital control, spacecraft commanding and control, telemetry analysis and reaction, and SAR control functions.	Spacecraft mission control skills possessed by Optus and will shortly be acquired by Newsat and NBNCo. Required to be disseminated.	Training at MCS software provider eg Integral Systems. Training at spacecraft prime and Optus satellite control in Australia.
Ground Segment Ground Station Subsystem	Design, development and commissioning of facilities, hardware and software to undertake the RF transmission and reception to/from the space segment. Includes telemetry, command, control and data links, ranging, and timing.	None	
Ground Segment Support Subsystem	Generation and provision of the test equipment, spares, operating and maintenance manuals and procedures, and operator and maintainer training required to support the ground segment.	V&V of spacecraft software.	Training at spacecraft prime in the validation and acceptance of the spacecraft subsystem software from suppliers. Participation as part of the software integration and test team during AIT at the prime.
Ground Segment Integration and Verification testing	Integration and test of the ground segment including interfacing with the space segment.	None	
Project Management	Integration and test of the ground segment including interfacing with the space segment.	None	

Task	Australian Industry Involvement	Australian skill delta	Means of addressing
Mission Operations	Mission analysis, simulation, planning, scheduling, monitoring and control, performance analysis.	None	
Payload operations	SAR operations analysis, planning, scheduling, calibration and control.	SAR operations and calibration	Undertake training at SAR prime contractor. Australian engineers resident at SAR prime during design phase for SAR operational knowledge transfer.
Payload Data Operations	Payload data reception, processing, archiving and distribution of first order data products.	SAR processing specific to the Garada SAR	Secondment of engineers into the prime contractor's SAR design team to learn SAR data streams and first order processing. Prime contractor SAR engineers resident in Australia during phase C/D.
Value Added Processing	Analysis of customer needs, algorithm development and refinement, data processing, data distribution, customer interfacing, user applications and services.	SAR processing, fusing of SAR and optical data. Generation of application specific SAR products	Creation of a national centre of SAR expertise, cooperative programs with overseas space agencies and universities.
Integrated Logistics Support (ILS)	System maintenance and obsolescence management, performance analysis and reporting, software development and validation.	None	

9. Roadmap

The roadmap for Australian industry involvement is shown in Figure 4 and Figure 5 against a backdrop of the project's major phases and reviews.

Figure 4 illustrates the roadmap for the space and ground segments. This follows the route of identifying the key strategic interests of Australia, in terms of supporting future space instruments, cubesats and microsats, and illustrates how the capabilities and skills obtained through Garada activities map into this strategy. It can be seen how the key skill deltas required for Garada to undertake the niche Australian space capabilities described in section 8.3 are fulfilled early in the project by collaboration with the space segment prime. This early training and knowledge transfer allows Australian industry to support the key phases C/D of the project.

Figure 5 illustrates the roadmap for the downstream value added services. Early focus is made on the up skilling of the Australian EO workforce to develop the use of existing SAR technologies and make them more widely available within the EO community. As the SAR skill base develops and broadens, the application to unique Australian tactical and strategic issues will grow and demonstrate the strengths of the all-weather, wide area imaging capabilities of SAR. Australian participation with the SAR designers in the early stages of the SAR development allows the core processing algorithms that are uniquely required for the Garada SAR to be developed prior to their productionisation and deployment in phase D of the ground segment. Development of specific algorithms to undertake the core applications of Garada, such as soil moisture measurement, are commenced early in the lifecycle through Australian R&D and evaluated using data from forthcoming L Band SARs; eg SAOCOM and PALSAR. This program of integrated activities ensures Australia is able to maximise the value of its investment in the Garada program both during the design / development and ongoing operation.

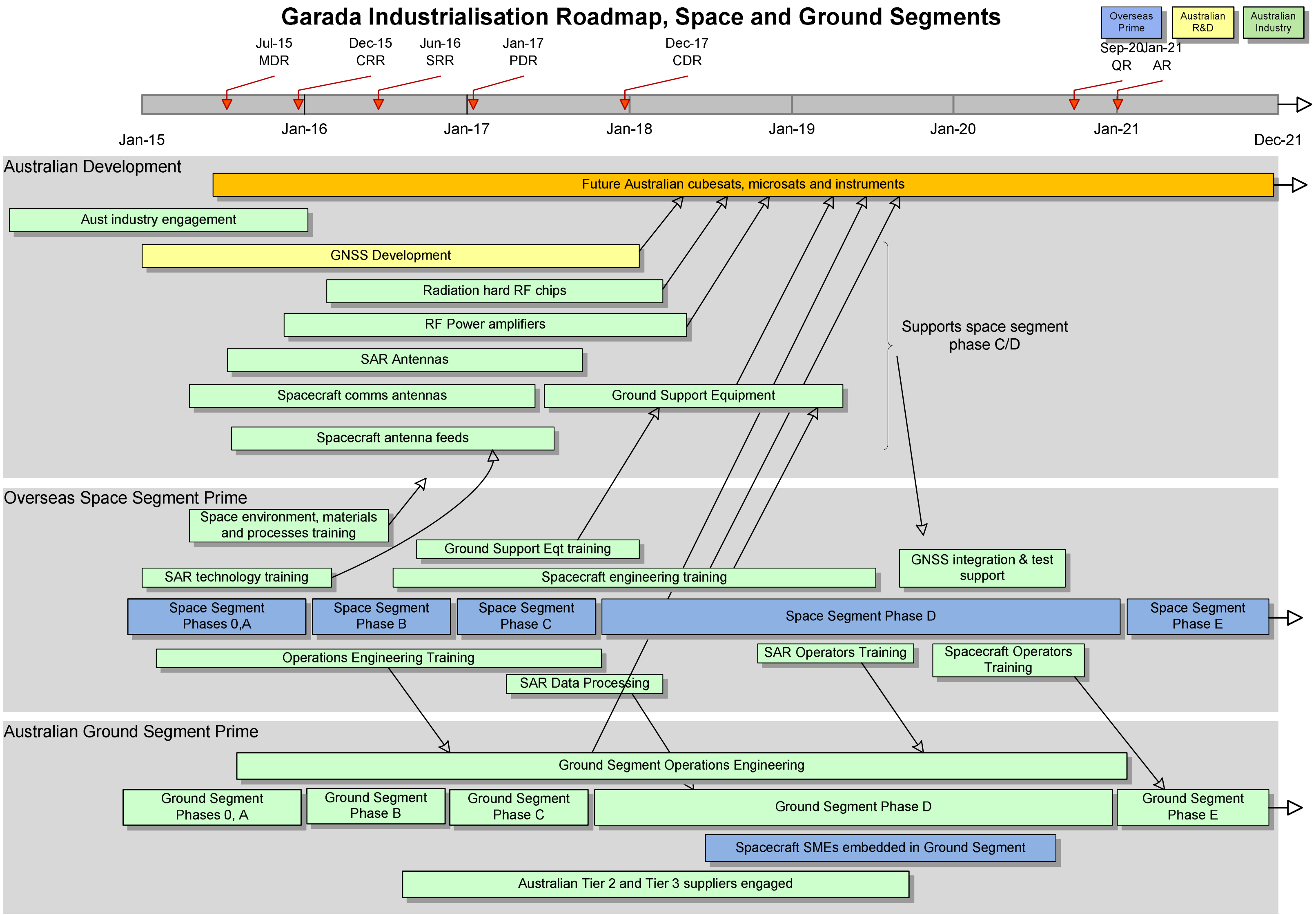

Figure 4: Industrialisation Roadmap, Space and Ground Segments

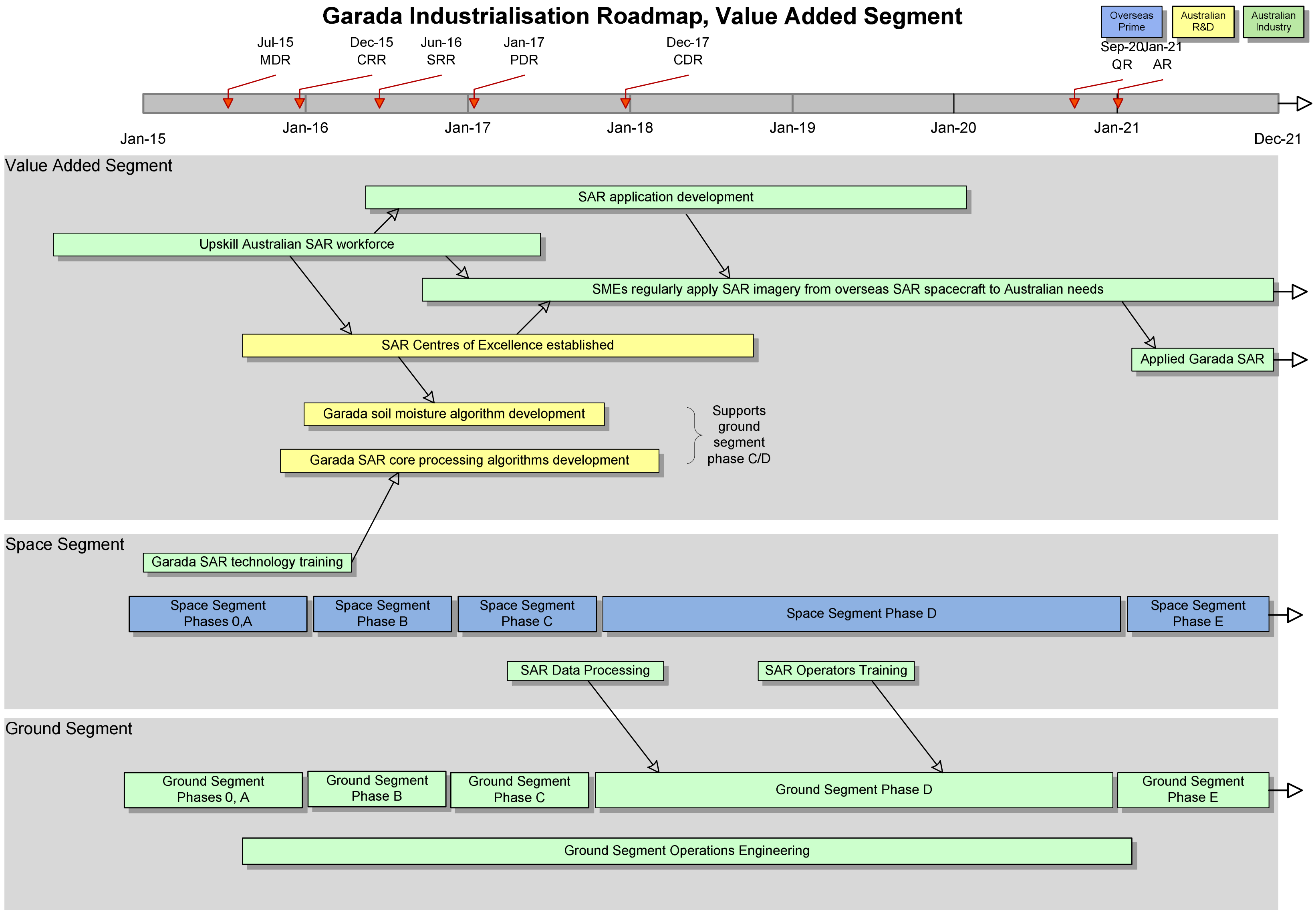

Figure 5: Industrialisation Roadmap, Value Added Segment

10. Australia's Satellite Utilisation Policy

A brief description of Australia's Satellite Utilisation Policy is provided in Section 5. In that section the high level aims from the Satellite Utilisation Policy that are applicable to Garada are described. The Garada mission and the Australian involvement in the mission need to be congruent with these aims to achieve long term strategic benefits for Australia. Potential tasks for Australian industry involvement are detailed in section 8.1. The contribution each of the Garada tasks makes towards the achievement of these high level policy aims is shown in Table 6: Achievement of Policy Aims Through Garada Industrial Involvement. Table 7 lists the policy aims referenced in Table 6.

Table 6: Achievement of Policy Aims Through Garada Industrial Involvement

Garada Australian Industry Involvement Task	Policy Aims Addressed				
	a	b	c	d	e
Legal, Insurance, Risk and Safety		x			
Garada Systems Engineering	x	x			x
Spacecraft communications subsystem	x	x		x	x
SAR Antenna Structure	x	x		x	x
SAR Antenna RF Radiator	x	x		x	x
SAR Antenna Drive electronics	x	x		x	x
GNSS Systems Engineering	x	x		x	
GNSS Antenna	x	x		x	
GNSS Receiver	x	x		x	
GNSS Integration and Test.	x	x		x	
Ground Support Equipment for Spacecraft	x	x		x	x
Ground Segment Systems Engineering	x	x			x
Ground Segment Mission Management & Data Processing Subsystem	x	x			
Ground Segment Mission Control Subsystem	x	x			
Ground Segment Ground Station Subsystem	x	x			
Ground Segment Support Subsystem	x	x			
Ground Segment Integration and Verification Testing	x	x			
Project Management	x	x			
Mission Operations	x	x	x		
Payload Operations	x	x	x		
Payload Data Operations	x	x	x		
Integrated Logistics Support	x	x	x		
Value Added Processing	x	x	x		x

Table 7: Policy Aims Applicable to Garada

a	Prioritise research focused on earth observations from space, satellite communication and positioning, navigation and timing. (Principle 1)
b	Build and retain high quality Australian space expertise. (Principle 6)
c	Ensure Australia has the infrastructure, capabilities and skills to access, process, store, integrate, use and distribute the data and information from space systems. (Principle 2)
d	Develop Australian systems, sensors, hosted payloads or (small) satellites. (Principle 2)
e	Facilitate academic, inter-government and industry exchanges with appropriate international partners. (Principle 6)

11. Australian Industry Participation Plans

11.1. Introduction

The Australian government has effected a nationally consistent approach to maximise Australian Industry Participation (AIP) in government investment and procurement projects. This framework aims to recognise the benefits to the economy of local industry participation and consists of a set of objectives, principles and strategies designed to strengthen local industry participation. The framework is based on giving Australian industry full, fair and reasonable opportunity to participate in government projects. All projects exceeding $20m are now required to have an Australian Industry Participation (AIP) plan to be compiled and approved. The Garada mission has a scope comprising the development, manufacture and launch of two spacecraft; design and development of ground facilities for the monitoring and control of the spacecraft, reception, processing and distribution of payload data; and ongoing operation for seven years. The mission and individual segments will all exceed the threshold of $20m and will require AIP plans to be compiled and approved.

A summary of the requirements of an AIP plan is provided in Annex 1. An outline of a Garada plan that fulfils these requirements showing how AIP objectives can be achieved is provided in the following section.

12. Outline Australian Industry Participation Plan

12.1. Communication Strategy

The tier 1 contractors will require an effective communication strategy for the early identification of opportunities for Australian industry and the transfer of information regarding these opportunities to Australian industry. This needs to be done not only for the prime contractor but also for all subcontractors and suppliers. To support this, the organisations will need to actively seek information on Australian industry. Identifying and encouraging new suppliers is an important part of the AIP strategy.

Strategies that could be taken to communicate and increase opportunities for Australian industry include:

12.1.1. Websites

Use of a dedicated project website that is easily accessible from the prime’s main corporate website to detail the project, the opportunities available to Australian industry, the capabilities required and how interested industries can respond to the opportunities. Undertake the sending of regular newsletters to everyone who registers notifying of new opportunities and the release of new work packages.

12.1.2. Industry Capability Network

The Industry Capability Network (ICN) is a business network that introduces Australian and New Zealand companies to projects. It offers a new business source for suppliers and a search service for buyers. Projects can be registered with the ICN and provided with their own dedicated web page. The ICN can be used to communicate upcoming procurement and contracting opportunities that suppliers can search and browse. The site can also serve as a web portal to enable prospective suppliers to register expressions of interest or download tender requirements. The ICN supports supplier “pull” and buyer “push”. In the latter, automatic notifications are sent to registered suppliers when new work packages are listed. The ICN has offices in each state and can assist in matching required products and services to local industry capabilities.

12.1.3. Industry Bodies

Industry bodies such as the Space Industry Association of Australia and Spatial Industries Business Association can help identify capable Australian companies who are able to supply goods and services to the project throughout all tiers of supply and all phases of the project.

These industry bodies can also help disseminate information about the project to relevant Australian companies and advise on the business culture of the industry.

To ensure comprehensive coverage of appropriate industries, adjacent industry bodies should be covered as well. Adjacent bodies that could help with the identification of capable companies and dissemination of information include the Australian Industry and Defence Network, Defence Industry Association, Surveying and Spatial Sciences Institute, Australian Spatial Information Business Association Limited, and Engineers Australia,

12.1.4. Public Roadshows

To increase awareness in the available opportunities, public briefings can be held across the country to brief interested parties on the opportunities available for Australian industry and information on how the industries can seek further details and respond to the opportunities. Notices of briefings can be placed in the public notices sections of major national newspapers, industry journals and publicised on corporate websites.

12.1.5. Approved Suppliers

To aid the accreditation of new companies, an Approved Suppliers guide can be published that provides information on the criteria a company must meet to be able to supply to the project and how a prospective supplier can obtain this accreditation.

12.2. Opportunities through all tiers of supply and all stages

As described in section 8.1.1.1 the spacecraft industry operates through many tiers and the best opportunities for Australian industry involvement in the space segment are at the lowest tiers of components and parts suppliers. Such opportunities are unlikely to be direct suppliers into the Tier 1 company but suppliers somewhat down the subcontracting chain. The AIP plan commitments will need to cascade down to the lower level suppliers. This can be done by specifying in tender documents that successful suppliers will need to engage with and involve Australian industry at all tiers of the supply chain. The tender assessment process will assess the AIP to determine the Australian involvement to meet the strategic interests. Tier 2 and Tier 3 AIP strategies will need to be described, and a weighting allocated in the assessment process based on the perceived risk. It can be emphasised to the Tier 1 tenderers that heavy weighting will be allocated to the flow down of AIP for strategic capabilities during the competitive tender assessment process. (Refer section 10 for more on Garada strategic capabilities flowing from the Satellite Utilisation Policy)

Where Tier 1 companies procure work with established suppliers to source mature qualified subsystems with established pedigrees on previous programs, there can be great reluctance to change the suppliers of even low level components and parts due to the perceived reliability and performance risk such a change would entail. In these cases, which usually involve the occasional supply of low volume items, the cost to Australian industry to undertake the supply and the long term benefits that would result are probably not sufficient to make it worthwhile. Nonetheless, the example of the Australian semiconductor company Silana shows that it is still possible for an Australian supplier to penetrate spacecraft global supply chains with a niche product, in this case radiation hardened semiconductors.

12.3. Standards to be used in the project

Suppliers offering opportunities to Australian industry will need to specify the standards that will be applied when undertaking the project. If in house or proprietary standards are used, especially in the case of spaceflight componentry and systems, these need to be detailed and the process for accreditation to these standards explained. If international standards are used, such as NASA or European ECSS standards and processes, details of accreditation that are acceptable to the customer organisation will need to be provided. Suppliers offering opportunities for non spaceflight componentry should incorporate Australian standards into the design of the product to ensure maximum opportunities for Australian industry to participate.

12.4. Potential supplier assessment process.

After receiving registrations of interest from prospective suppliers via roadshows, web portals or industry associations it is necessary to assess the suitability of each supplier. At a roadshow it is possible to have the buyers' specialists meet with prospective suppliers and have a short, 5 – 15 minutes, interaction. Other suppliers can be sent a standard form and asked to undertake a self assessment followed up by a live discussion. From this information initial filtering of companies can take place to generate a short list of candidates. This can be followed up by a full on site assessment. This assessment is undertaken by specialists in each relevant area and will typically assess the potential supplier for:

i. Technical capability to provide the product or service; eg machining, plating, fabrication, wiring, coating, design, testing, etc.

ii. Business systems

iii. Management of IP

iv. Quality system

v. Continuous improvement of processes and product

vi. Configuration management

12.5. Opportunities for Australian involvement in global supply chains

A key long term goal of Australian Industry Participation is the sustainment of capability through the integration into global supply chains. Due to the small size of the indigenous market, Australian industry is characterised by low volume, high quality SME niche suppliers. It is also characterised by a lack of vertical integration and geographical separation of SMEs. A small or medium sized company located in Perth wishing to supply to the space segment may have its design and development team in Perth using the manufacturing and test facilities at the AITC in Canberra and conducting EMI/EMC testing in Melbourne. This makes it harder to compete with overseas suppliers who have all the facilities in house.

The space segment does not offer many opportunities for Australian industry to be integrated into global supply chains of the major players. The space industry is characterised by the supply of high cost, low volume, high reliability, space environment qualified systems and components. The cost of gearing up the design, processes and facilities required to meet these requirements for such low quantities is often uneconomic when starting from scratch. Supply of products into this specialist area becomes feasible when it is a by-product of another mainstream activity. Silanna Semiconductor sells Silicon on Sapphire radiation hard computer chips to the space industry for use on satellites and deep space probes. However, they have not set up a Silicon-on-Sapphire design and manufacturing facility because that process is radiation hard. But rather its lower intrinsic capacitance enables low noise, high isolation, high RF performance devices to be achieved. The radiation hardness that makes them attractive to space use is essentially a by-product of the use of a substrate with high insulating capabilities. There may be other niche products in Australian industry that could follow a similar course but these are expected to be the exception rather than the rule. One with potential is the space qualified GPS receiver and multi GNSS receiver being developed by NZ industry in conjunction with the University of New South Wales.

The earth observation satellite ground segment is a similar area of low demand. Understandably, specialist receivers, antennas, modems, and general purpose computing equipment are no longer produced by Australian industry. Niche Australian suppliers of custom antenna feeds and waveguides exist and they have potential to infiltrate global supply chains, though the volume can be expected to be low.

The downstream value added chain of application of SAR to resource management and the interpretation of the data to apply to specialist applications has potential for application to markets outside of Australia. These capabilities could be of value to the larger tier 1 suppliers wishing to offer a highly vertically integrated product to customers.

13. Contract Models

As described in Ref 1, the Australian Industry Capability Report for Garada, there are no Australian companies capable of undertaking the development and manufacture of the spacecraft required to fulfil the Garada mission. These Tier 1 companies are system integrators who design, integrate, and sell whole space systems to end users. This tier is dominated by a few very large companies from the US and Europe. These companies include Boeing, Lockheed Martin, Northrop Grumman, Space Systems Loral, Orbital Sciences Corporation, Ball Aerospace, MacDonald Dettwiler, EADS Astrium, and Thales Alenia. In contrast, the ground segment and ongoing operations execution are well within the capabilities of Australian industry.

A possible contract model is illustrated in Figure 6. In this model a Garada prime contractor, an overseas Tier 1 company that would also undertake the development and supply of the spacecraft, takes responsibility for the supply of both the space and ground segments. The ongoing operation of the mission is contracted separately by the Commonwealth. R&D activities of GNSS development and soil moisture algorithm research that are the speciality of Australian academic institutions are funded directly by the Commonwealth in the early part of the project. This allows the R&D work of Australian institutions to continue independent of the selection and contracting of the prime contractor. Deliverables from these activities would be provided to the prime as customer furnished equipment and information.

An alternative model, illustrated in Figure 7, has the contracting of the space segment, launch services and ground segment separately. This has the potential to have lower upfront contracting costs, and greater freedom and control over the selection of Australian industry, in exchange for the customer managing the interfaces between the segments and carrying the associated risks.

In both these contracting models, the Tier 1 contractors for the space and ground segments will be responsible for providing Australian Industry Participation plans. The contractors will be required to provide an AIC plan that explores all opportunities for Australian involvement, commensurate with project cost, risk and alignment with the expressed objectives in Australia's Satellite Utilisation Policy. They will also be responsible for flowing the requirement for AIP plans to their major suppliers. Whilst the responsibility for identifying the areas of Australian industry participation that fit with the final solution concept for Garada will be the domain of the Tier 1 contractors, Australian suppliers need to identify opportunities and market themselves to the primes. Likely opportunities for Australian participation that can be concluded from the design studies conducted in the Phase 0 activities and the capabilities of Australian industry identified in the Australian Industry Capability Report (Ref 1) are described in section 8.

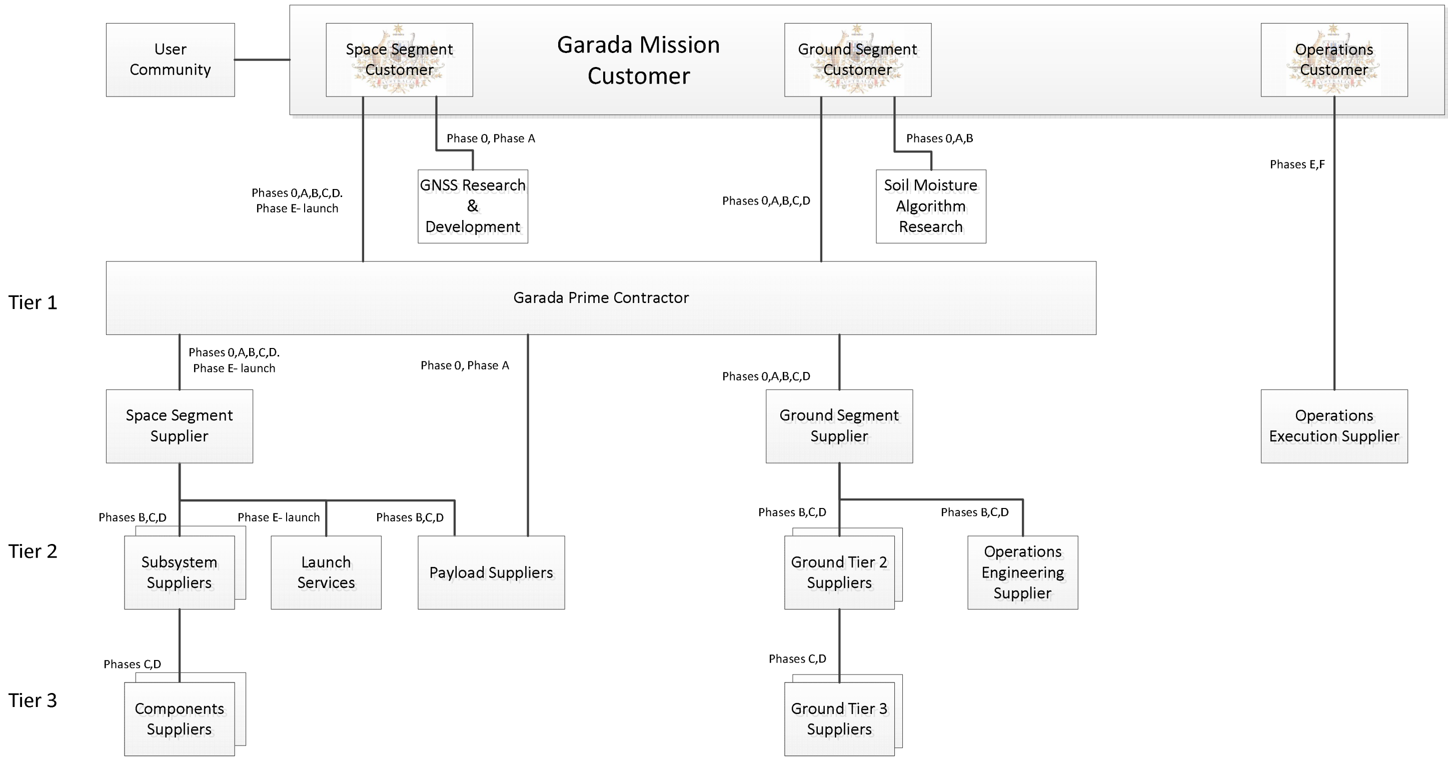

Figure 6: Candidate Contract Model for Garada Mission

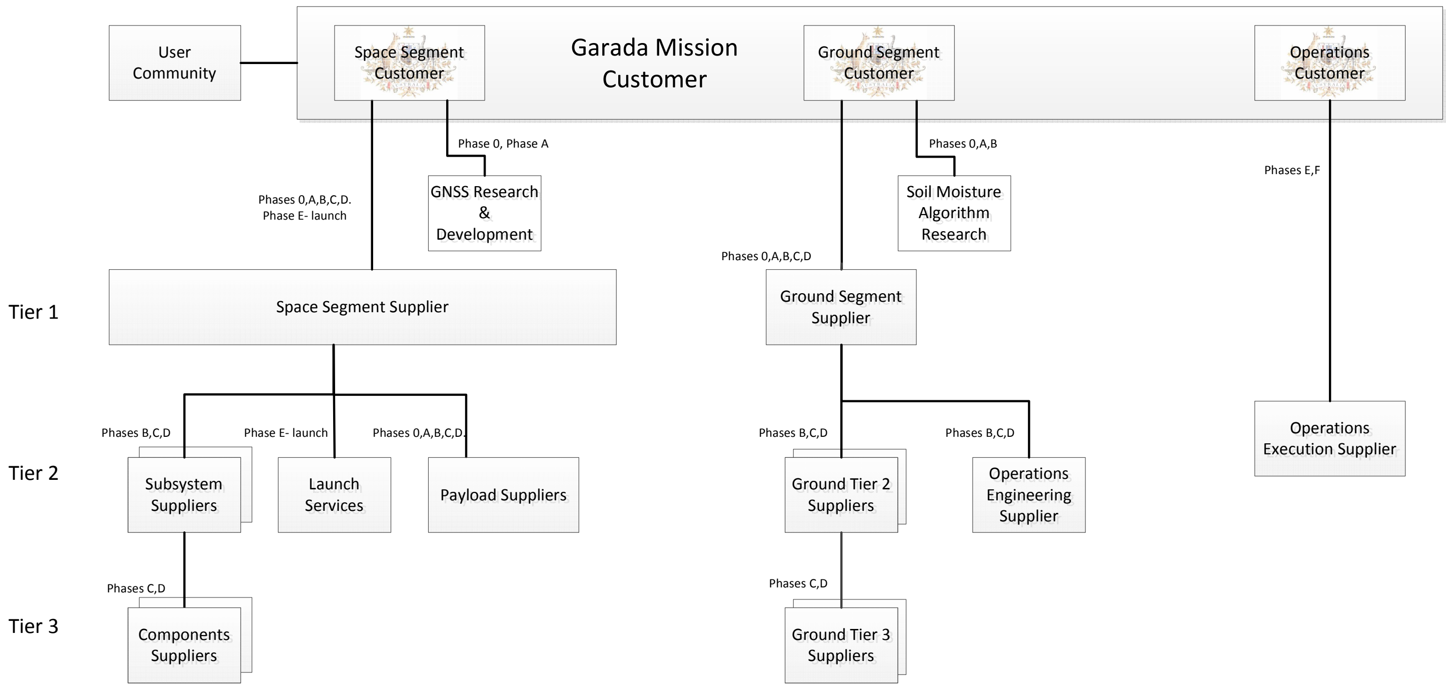

Figure 7: Alternative Contract Model for Garada Mission

Annex A The Australian Industry Participation Framework

1. The Australian Industry Participation Framework

1.1. Background to the Australian Industry Participation Framework.

Australia has effected a nationally consistent approach to maximise Australian Industry participation in government investment and procurement projects. This framework recognises the benefits to the economy of local industry participation and consists of a set of objectives, principles and strategies designed to strengthen industry participation. The framework is based on giving Australian industry full, fair and reasonable opportunity to participate in government projects.

i. **Full**: Australian industry has the same opportunity afforded to other global supply chain partners to participate in all aspects of a project (eg. design, engineering, project management, professional services, IT architecture);

ii. **Fair**: Australian industry is provided the same opportunity as global suppliers to compete on projects on an equal and transparent basis, and

iii. **Reasonable**: government tenders are free from non-market burdens that might rule out Australian industry and are structured in such a way as to provide Australian industries the opportunity to participate in government projects.

The Government has identified four strategic approaches to give effect to the framework. These are supported by policies and programs that work to maximise opportunities for Australian industry and encourage the development of strategic alliances. The strategic approaches are:

a. Encouraging industry to meet world's best practice through capability building

The Government is setting out to encourage industry to increase its capabilities and achieve world's best practice by building strategic alliances, improving access to competitive infrastructure, encouraging innovation and the uptake of technology and skills.

b. Early identification of opportunities for Australian industry participation, both domestically and overseas

The government aims to give valuable benefits to industry by acquiring timely information about emerging opportunities, both domestically and overseas. Early identification of potential projects improves the prospects for involving Australian industry capability and ongoing participation in global supply chains.

c. Promoting Australian Capability and Integrating Industry into Global Supply Chains

The Government undertakes marketing and promotion of Australian industry capability domestically and overseas through marketing campaigns, direct marketing and the use of industry capability databases and other relevant sources to enhance the prospects of Australian industry penetrating global supply chains.

d. Enhancing Project Facilitation and Australian Industry Participation

The Government requires companies involved in Australian projects to undertake Australian Industry Participation Plans (AIPPs). These offer the bidder an opportunity to familiarise itself with Australian capability, identify qualified suppliers and to secure valuable support for the project from industry. AIPPs also enable bidders to demonstrate a commitment to the principle of full, fair and reasonable opportunity. The Government is looking for an AIPP to include:

- a recognition of the importance of Australian participation in local and overseas projects and an acknowledgment of the value of exploring ongoing opportunities for Australian industry participation;
- a commitment to work constructively with Australian industry and the Industrial Supplies Office network to identify and develop options for increasing Australian industry participation in the project;
- a communication strategy that provides for:
  - early identification of opportunities for Australian participation; and
  - effective transfer of information on opportunities for Australian industry participation through all tiers of supply (eg. along sub-contracting chains);
- a commitment to develop and structure tenders for the supply of goods and services to the prime to provide full, fair and reasonable opportunity for Australian industry participation;
- support for the integration of Australian industry into global supply chains; and
- a recognition of the economic impacts of a project on Australian industry (eg. employment, skills transfer, strategic alliances and regional development) and the need for communication of these impacts.

1.2. Application to Procurements

On 28 July 2009, the Australian Government released its Australian Government Procurement Statement. In this Statement, the Australian Government announced it would strategically apply the Australian Industry Participation (AIP) National Framework (as described above) to large Commonwealth procurements (generally over $20 million), by requiring potential suppliers to prepare and implement AIP Plans. This policy has applied from 1 January 2010. This policy will consequently apply to the future procurement of the Garada mission by the Australian Government.

By applying the AIP National Framework to Commonwealth procurements the government is aiming at increasing the opportunities for Australian Small and Medium sized Enterprises (SMEs) to participate in major Commonwealth procurement activities. The AIP plan is a mechanism for potential suppliers to familiarise themselves with Australian SME capability and identify qualified suppliers. The AIP plan can also give Australian SMEs access to new opportunities, strategic partnerships and international supply chains.

1.3. When an AIP Plan is Required

The general guideline given by the Department of Industry, Innovation, Science, Research and Tertiary Education (DIISRTE) is that AIP plans are required for tenders valued at $20m or more, though the final decision will be made by DIISRTE.

Once it is determined that an AIP plan is required, potential suppliers are required to submit an approved AIP plan as part of the tender response. Achieving an approved AIP plan requires it to be submitted to DIISRTE and a certificate of approval received prior to the submission of the tender response. Failure to submit an approved AIP plan will result in exclusion from the tender evaluation process. On award of the contract, the successful tenderer will then be contractually obliged to implement their approved AIP plan. During contract execution the contractor will be required to supply regular (usually annually but could be more frequent) implementation reports to DIISRTE.

2. AIP Plan Content

The objective of an AIP plan is to:

- demonstrate how the organisation will provide full, fair and reasonable opportunity to Australian industry to supply goods and services to the project; and
- endeavour to maximise opportunities for Australian industry to participate in all aspects of the project.

An AIP Plan outlines the actions an organisation will take to provide Australian industry with full, fair and reasonable opportunity to participate in the project. The AIP Plan has to cover off the criteria described in the following paragraphs. To meet these criteria, organisations need to outline specific activities they intend to undertake to provide Australian industry, with full, fair and reasonable opportunity.

2.1. Opportunities for Australian industry

The plan provides detail on the goods and services to be procured for the project, an indication of expected areas of opportunity for Australian suppliers, and an estimate of the percentage of Australian industry value added for the project.

2.2. Communication strategy

The plan is required to provide detail on the organisation's communication strategy for the early identification of opportunities for Australian industry and the communication of information on opportunities for Australian industry through all tiers of supply (e.g. along sub-contracting chains).

This must include detail on how the organisation will actively seek information on Australian industry capability and communicate opportunities to potential suppliers.

2.3. Opportunities through all tiers of supply and in all stages of the project

The plan is to describe strategies to include Australian industry through all tiers of supply and all stages of the project (i.e. through phases A to E). It must also explain the process and criteria to assess potential suppliers.

2.4. Opportunities for longer-term participation

The plan needs to transcend the project itself and describe opportunities for longer-term participation by Australian industry, including how the project will work with suppliers to encourage capability development and integration into global supply chains.

2.5. Procedures and resources

The internal procedures, resources and systems in place to monitor the implementation of the AIP Plan are required to be described in the plan.

Annex B Training Program in SAR Technologies Program

Garada

Synthetic Aperture Radar Workshop

7th December 2011

Allens Arthur Robinson Theatre (G23)
Law Building
The University of New South Wales

UNSW
THE UNIVERSITY OF NEW SOUTH WALES

ACSER
AUSTRALIAN CENTRE FOR SPACE ENGINEERING RESEARCH

BAE SYSTEMS

Time	Topic	Speaker
8:00 am	Arrival & registration	
8:30 am	**Welcome** *Overview of Project Garada and workshop objectives*	Andrew Dempster **UNSW**
8:45 am	**SAR Techniques** *Fundamental principles, phenomenology, sensitivity and system design*	David Hall **Astrium**
10:10 am	**SAR Technologies** *Antenna types, power amplification, instrument control and pulse waveform generation*	Martin Cohen **Astrium**
10:30 am	*Morning Tea (hosted by BAE Systems)*	
10:45 am	**SAR Data Processing and Product Generation (Monostatic)** *Image formation, image rectification, radiometric calibration, polarimetric calibration and exploitation*	Nick Stacy **DSTO**
11:25 am	**Evolution from Monostatic to Bistatic SAR**	Robert Middleton **UNSW**
11:35 am	**Benefits of SAR Formation-Flying Satellites**	Steven Tsitas **UNSW**
12 noon	*Buffet Lunch (hosted by BAE Systems)*	
12:45 pm	Group photograph	
1:00 pm	**Application of SAR for Emergency Response during the 2011 Queensland Floods**	Norman Mueller **Geoscience Australia**
1:45 pm	**Land Cover Classification using Interferometric SAR**	Syed Ali **DIGO**
2.30 pm	**Garada SAR Formation-Flying System Architecture**	Steven Tsitas **UNSW**
3:00 pm	*Afternoon Tea (hosted by BAE Systems)*	
3:15 pm	**Guided discussion session:** *SAR Satellite Trends* *Garada Cost Drivers* *Garada SAR Technology Drivers* *Garada Satellite Platform Design*	**Panel Members** · Andrew Dempster · Martin Cohen · Nick Stacy · Steven Tsitas **Facilitator** David Hall
5:30 pm	Workshop Close	

Annex C Capability Requirements Matrix

Task			
ID #	Task Name	Product Description (the scope of the items the task is concerned with)	Workscope Description (work to be performed for the task)
1	Garada Implementation		
1.1	Systems Engineering Garada Mission	The Garada mission across all phases of its lifecycle.	Finalise customer needs, mission analysis and modelling, regulatory compliance, identify performance drivers, constraints, operational scenarios; analyse and select final solution; write mission description document, trade off report, technical requirement specification, interface requirements document; support of engineering reviews including: mission definition review, preliminary requirement review, preliminary design review, critical design review, qualification review, acceptance review, operational readiness review.
1.2	Space Segment		
1.2.1	Systems Engineering Space Segment	Systems Engineering of the space segment.	CD1
1.2.2	Spacecraft		
1.2.2.1	Platform		
1.2.2.1.1	Systems Engineering spacecraft platform	Systems Engineering of the platform subsystem.	CD1
1.2.2.1.2	Structure	The structural body of the spacecraft to which the harness and other subsystems and payloads are mounted. It is designed to take all loadings encountered during transportation, handling, testing, pre launch, launch, and operation activities and withstand the effect of material degradation in both the terrestrial and space environments.	CD1, CD2
1.2.2.1.3	Attitude and Orbital Control	The AOC subsystem consists of sensors, control algorithms and actuators (thrusters, torquers etc.) to control the correct orientation of the spacecraft with respect to the earth and sun; to manoeuvre it into its operational orbit after launch and to maintain the spacecraft within its orbit during its operational lifetime including formation flying, conjunction avoidance and de-orbit.	CD1, CD2
1.2.2.1.4	Harness	The spacecraft wiring and backplanes for the distribution of power and data between the spacecraft subsystems.	CD1, CD2
1.2.2.1.5	OBDH	The On-board Data Handling subsystem that carries and stores data between the spacecraft subsystems and the ground segment via the communications subsystem for telemetry, tracking, command and payload data	CD1, CD2
1.2.2.1.6	Communications	The on-board spacecraft communication subsystem that manages the RF link to the ground segment for telemetry, tracking, command and payload data.	CD1, CD2
1.2.2.1.7	Thermal control	The thermal control system consists of sensors, algorithms and heaters to maintain the on-board equipment in the correct temperature range during its life to guarantee optimal performance when the equipment is operating and to avoid damage when equipment is not operating.	CD1, CD2
1.2.2.1.8	Power		
1.2.2.1.8.1	Solar Array	The cells, array, structure, deployment and control mechanisms for the spacecraft solar array.	CD1, CD2
1.2.2.1.8.2	Power storage	The batteries or other electrical energy storage devices, battery management electronics and battery thermal control.	CD1, CD2
1.2.2.1.8.3	Power regulation and control	The electronics to perform conditioning, regulation, control and distribution of the spacecraft power.	CD1, CD2
1.2.2.1.9	Integrate and test	Platform integration and test procedures and results	Integration, development, qualification and acceptance testing of the platform subsystems into the platform system.
1.2.2.2	Payload		
1.2.2.2.1	SAR		
1.2.2.2.1.1	Systems Engineering SAR payload	Systems engineering of the SAR payload	CD1
1.2.2.2.1.2	Antenna		
1.2.2.2.1.2.1	Structure	The SAR antenna structure to accommodate the drive electronics, RF radiator, feed networks and deployment and control mechanisms and sensors.	CD2

Task ID #	Task Name	Product Description (the scope of the items the task is concerned with)	Workscope Description (work to be performed for the task)
1.2.2.2.1.2.2	RF radiator	The RF radiating and receiving elements of the antenna.	CD2
1.2.2.2.1.2.3	Drive electronics	The SAR drive electronics including HPA chips, LNAs, Tx phase shifters, solid state switchers, Rx phase shifters, Receive gain control, interface and control electronics.	CD2
1.2.2.2.1.3	Central Electronics	The SAR timing generator, reference oscillator, Tx signal generator and amplification chain, receive chain, interface to the OBDH.	CD2
1.2.2.2.1.4	Global Navigation Satellite Subsystem		
1.2.2.2.1.4.1	Systems Engineering GNS	Systems engineering of the GNS subsystem	CD1
1.2.2.2.1.4.2	Antenna	The GNS system antennas.	CD2
1.2.2.2.1.4.3	Receiver	The GNS receiver and interface card.	CD2
1.2.2.2.1.4.4	Integrate and Test	GNS subsystem integration and test procedures and results	Integration, development, qualification and acceptance testing of the GNS card and antennae
1.2.2.2.1.5	Integrate and Test	SAR payload integration and plans, procedures and results	Integration and testing of the SAR payload and the GNS card into the SAR system.
1.2.2.3	Assembly, Integration and Test		
1.2.2.3.1	Assembly	Spacecraft integration plans, procedures and results	Assembly of the subsystems into the spacecraft system.
1.2.2.3.2	Integration	Spacecraft integration plans, procedures and results.	Integration of the subsystems into the spacecraft systems, integration of spacecraft into launcher mount, integration of space segment with the ground segment; functional testing using integration test threads and ground support equipment.
1.2.2.3.3	Test		
1.2.2.3.3.1	Qualification Testing	Spacecraft qualification test plans, procedures and results	Undertake testing and analysis to verify that the spacecraft conforms to the specified requirements.
1.2.2.3.3.2	Acceptance Testing	Satellite acceptance test plans, procedures and results.	Undertake testing to demonstrate that the delivered spacecraft conforms to the specified requirements.
1.2.3	Ground Support Equipment		
1.2.3.1	Platform	All mechanical (MGSE) and electrical (EGSE) ground equipment required to support the assembly, integration and test of all models of the platform including subsystems within the platform. Includes jigs and fixtures, interface simulators, data recorders, analysis tools.	CD3
1.2.3.2	Payload	All MGSE and EGSE ground equipment required to support the assembly, integration and test of all models of the payload. Includes jigs and fixtures, interface simulators, data recorders, analysis tools.	CD3
1.2.3.3	Spacecraft	All MGSE and EGSE ground equipment required to support the assembly, integration and test of all models of the spacecraft. Includes jigs and fixtures, interface simulators, data recorders, analysis tools.	CD3
1.3	Launch Service Segment		
1.3.1	Launch vehicle selection	Selection of the launch vehicle for the Garada spacecraft.	Selection of launch vehicle considering lift capacity, maximum altitude, orbit inclination, vibration environment etc.
1.3.2	Payload integration	Interfacing of all Garada Spacecraft to the launch vehicle.	Spacecraft to launcher interface design, manufacture and test.
1.3.3	Pre launch	Pre launch activities for the Garada spacecraft.	Integration of spacecraft to launcher.
1.3.4	Launch	Launch services agreement and launch of Garada spacecraft.	Spacecraft launch and deployment into orbit.
1.4	Ground Segment		
1.4.1	Systems Engineering Ground Segment	Systems engineering of the ground segment.	CD1
1.4.2	Mission Management and Data Processing Subsystem	Facilities, hardware and software to undertake the SAR Data Processing, SAR image interpretation, archiving, processing of customer requests, scheduling & prioritising of imaging activities.	CD3
1.4.3	Mission Control Subsystem	Facilities, hardware and software to undertake control of the Garada mission including attitude and orbital control, spacecraft commanding and control, telemetry analysis and reaction, and SAR control functions.	CD3
1.4.4	Ground Station Subsystem	Facilities hardware and software to undertake the RF transmission and reception to/from the space segment. Includes telemetry, command, control and data links, ranging, and timing.	CD3
1.4.5	Support Subsystem	The test equipment, spares, operating and maintenance manuals and procedures, and operator and maintainer training required to support the ground segment.	CD3
1.4.6	Integration and Verification testing	Integration and test of the ground segment including interfacing with the space segment.	Integration of the subsystems comprising the ground segment and integration of the ground segment with the space segment. Verification of the ground segment including functionality and interfaces, subsystem testing, segment integration testing and operations validation testing.
1.5	Project Management	Project and commercial management of the Garada system development, including space and ground segments and launch and deployment.	Workscope planning and implementation, configuration and information management, cost and schedule management, risk management, commercial management.
2	Garada Operation		
2.1	Mission Operations	The operational Garada system.	Mission analysis, simulation, planning, scheduling, monitoring and control, performance analysis.
2.2	Payload operations	The operational Garada system.	SAR operations analysis, planning, scheduling and control.

Task			
ID #	Task Name	Product Description (the scope of the items the task is concerned with)	Workscope Description (work to be performed for the task)
2.3	Payload Data Operations	The operational Garada system.	Payload data reception, processing, archiving, distribution. Customer interfacing, user services.
2.4	Integrated Logistics Support	Maintain and upgrade the ground segment.	System maintenance and obsolescence management, performance analysis and reporting, software development and validation.

Task		**Required Capability** (the capabilities required to undertake the work scope for the product)																																																								
ID #	Task Name	Sys Eng.		Specialist Eng Capabilities					Electrical Eng						Mech Eng.					SW Eng.	Communications Eng					Control Eng		Testing												Ground Systems						Launch	Product Assurance									Project Management			
									Power					EMC									RF Systems																												Materials Parts and Processes							
		Systems Engineering	Space Environment	Rad hard chip fabrication	L band antennas	L Band semiconductor design	GPS and satnav systems	Space based SAR Systems	Solar cells and arrays	Solar array drives	Batteries & power storage	Power conditioning and control	Harnesses	EMC/EMI	Thermal control	Structures	Materials	Mechanisms	Propulsion	SW Engineering	Space data links- Telemetry	Space data links- Command	RF and modulation	Antennas	RF power amps	Control engineering	Attitude and Orbital Control	Physical properties	Functional and Performance	Leak & Pressure	Acceleration	Vibration	Acoustic	Shock	Thermal vacuum	Thermal cycling	EMC/ESD	Microgravity	Thermal balance	Operations Control	Payload control	Ground station	Communications networks	SAR data processing	Ground segment verification	Launch Services	Quality Assurance	Use of off the shelf items in space s	Dependability	Safety	EEE components	Selection of space materials & proc	Cleanliness control	Material testing	Assembly processes	Project Management	Commercial	Integrated Logistics Support	
1	Garada Implementation																																																										
1.1	Systems Engineering Garada Mission	x	x																																															x									
1.2	Space Segment																																																										
1.2.1	Systems Engineering Space Segment	x	x																																															x									
1.2.2	Spacecraft																																																										
1.2.2.1	Platform																																																										
1.2.2.1.1	Systems Engineering spacecraft platform	x	x																																															x									
1.2.2.1.2	Structure	x														x												x				x															x	x	x			x	x	x	x				
1.2.2.1.3	Attitude and Orbital Control	x												x					x	x						x	x	x	x	x		x		x	x	x	x										x	x	x		x	x	x	x	x				
1.2.2.1.4	Harness	x											x	x														x	x			x			x	x											x	x	x		x	x	x	x	x				
1.2.2.1.5	OBDH	x												x						x								x	x			x			x	x	x										x	x	x		x	x	x	x	x				
1.2.2.1.6	Communications	x												x				x		x	x	x	x	x	x			x	x		x	x		x	x	x	x	x									x	x	x		x	x	x	x	x				
1.2.2.1.7	Thermal control													x	x					x						x		x	x			x			x	x	x										x	x	x		x	x	x	x	x				
1.2.2.1.8	Power																																																										
1.2.2.1.8.1	Solar Array	x							x	x				x				x										x	x				x		x												x	x	x		x	x	x	x	x				
1.2.2.1.8.2	Power storage	x									x			x														x	x	x		x		x	x	x											x	x	x		x	x	x	x	x				
1.2.2.1.8.3	Power regulation and control	x										x		x						x						x		x	x			x		x	x	x	x										x	x	x		x	x	x	x	x				
1.2.2.1.9	Integrate and test																											x	x			x					x										x						x						
1.2.2.2	Payload																																																										
1.2.2.2.1	SAR																																																										
1.2.2.2.1.1	Systems Engineering SAR payload	x	x					x																																										x									
1.2.2.2.1.2	Antenna																																																										
1.2.2.2.1.2.1	Structure	x						x								x		x										x	x		x	x			x	x		x									x	x	x			x	x	x	x				

Task		Required Capability (the capabilities required to undertake the work scope for the product)																																																							
ID #	Task Name	Sys Eng.		Specialist Eng Capabilities					Electrical Eng						Mech Eng.					SW Eng.	Communications Eng					Control Eng		Testing												Ground Systems						Launch	Product Assurance									Project Management		
									Power					EMC									RF Systems																													Materials Parts and Processes						
		Systems Engineering	Space Environment	Rad hard chip fabrication	L band antennas	L Band semiconductor design	GPS and satnav systems	Space based SAR Systems	Solar cells and arrays	Solar array drives	Batteries & power storage	Power conditioning and control	Harnesses	EMC/EMI	Thermal control	Structures	Materials	Mechanisms	Propulsion	SW Engineering	Space data links- Telemetry	Space data links- Command	RF and modulation	Antennas	RF power amps	Control engineering	Attitude and Orbital Control	Physical properties	Functional and Performance	Leak & Pressure	Acceleration	Vibration	Acoustic	Shock	Thermal vacuum	Thermal cycling	EMC/ESD	Microgravity	Thermal balance	Operations Control	Payload control	Ground station	Communications networks	SAR data processing	Ground segment verification	Launch Services	Quality Assurance	Use of off the shelf items in space s	Dependability	Safety	EEE components	Selection of space materials & proc	Cleanliness control	Material testing	Assembly processes	Project Management	Commercial	Integrated Logistics Support
1.2.2.2.1.2.2	RF radiator	x		x	x			x						x										x				x	x		x																x	x	x			x	x	x	x			
1.2.2.2.1.2.3	Drive electronics	x		x		x		x						x											x			x	x			x		x	x	x	x										x	x	x		x	x	x	x	x			
1.2.2.2.1.3	Central Electronics	x						x						x						x								x	x			x		x	x	x	x										x	x	x		x	x	x	x	x			
1.2.2.2.1.4	Global Navigation Satellite Subsystem																																																									
1.2.2.2.1.4.1	Systems Engineering GNS	x	x				x																																											x								
1.2.2.2.1.4.2	Antenna	x					x							x				x										x	x			x		x	x	x		x									x	x	x			x	x	x	x			
1.2.2.2.1.4.3	Receiver	x					x							x						x								x	x			x		x	x	x	x										x	x	x		x	x	x	x	x			
1.2.2.2.1.4.4	Integrate and Test																											x	x								x										x						x					
1.2.2.2.1.5	Integrate and Test																											x	x			x					x										x						x					
1.2.2.3	Assembly, Integration and Test																																																									
1.2.2.3.1	Assembly																																														x						x		x			
1.2.2.3.2	Integration																												x																		x						x					
1.2.2.3.3	Test																																																									
1.2.2.3.3.1	Qualification Testing	x																										x	x			x		x	x	x	x		x								x						x					
1.2.2.3.3.2	Acceptance Testing	x																										x	x			x															x						x					
1.2.3	Ground Support Equipment																			x									x																		x											
1.2.3.1	Platform	x																																													x			x								
1.2.3.2	Payload	x																																													x			x								
1.2.3.3	Spacecraft	x																																													x			x								
1.3	Launch Service Segment																																																	x								
1.3.1	Launch vehicle selection	x																																												x												
1.3.2	Payload integration															x	x												x																	x												
1.3.3	Pre launch																																													x												
1.3.4	Launch																																													x												
1.4	Ground Segment																																																									
1.4.1	Systems Engineering Ground Segment	x																																																x								
1.4.2	Mission Management and Data Processing Subsystem	x																										x	x														x	x	x		x											
1.4.3	Mission Control Subsystem	x																										x	x											x	x		x		x		x											
1.4.4	Ground Station Subsystem	x																										x	x													x	x		x		x											
1.4.5	Support Subsystem	x																										x	x																		x											
1.4.6	Integration and Verification testing	x																										x	x																x		x											
1.5	Project Management																																																							x	x	
2	Garada Operation																																																									
2.1	Mission Operations																																							x		x	x													x	x	
2.2	Payload operations																																								x															x	x	

Task | **Required Capability** (the capabilities required to undertake the work scope for the product)

ID #	Task Name	Systems Engineering	Space Environment	Rad hard chip fabrication	L band antennas	L Band semiconductor design	GPS and satnav systems	Space based SAR Systems	Solar cells and arrays	Solar array drives	Batteries & power storage	Power conditioning and control	Harnesses	EMC/EMI	Thermal control	Structures	Materials	Mechanisms	Propulsion	SW Engineering	Space data links- Telemetry	Space data links- Command	RF and modulation	Antennas	RF power amps	Control engineering	Attitude and Orbital Control	Physical properties	Functional and Performance	Leak & Pressure	Acceleration	Vibration	Acoustic	Shock	Thermal vacuum	Thermal cycling	EMC/ESD	Microgravity	Thermal balance	Operations Control	Payload control	Ground station	Communications networks	SAR data processing	Ground segment verification	Launch Services	Quality Assurance	Use of off the shelf items in space s	Dependability	Safety	EEE components	Selection of space materials & proc	Cleanliness control	Material testing	Assembly processes	Project Management	Commercial	Integrated Logistics Support	
		Sys Eng.		Specialist Eng Capabilities					Electrical Eng – Power					E M C	Mech Eng.					SW Eng.	Communications Eng		RF Systems			Control Eng		Testing												Ground Systems						Launch	Product Assurance					Materials Parts and Processes				Project Management			
2.3	Payload Data Operations																																											x												x	x		
2.4	Integrated Logistics Support																																																							x	x	x	