Quarantine Review of the MUSES-C Project

Surface sample returned from asteroid 1998 SF36

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AGRICULTURE, FISHERIES AND FORESTRY - AUSTRALIA

Contents

GLOSSARY OF TERMS AND ABBREVIATIONS

Act	the *Quarantine Act 1908*
AFFA	the Commonwealth Department of Agriculture, Fisheries and Forestry - Australia
AQIS	Australian Quarantine and Inspection Service
Biosecurity Australia	A major operating group within AFFA. Biosecurity Australia protects consumers and animal and plant health, and facilitates trade, by providing sound scientifically based and cost effective quarantine policy
CFRP	Carbon Fibre Reinforced Plastic
COPUOS	Committee on the Peaceful Uses of Outer Space of the United Nations
COSPAR	Committee on Space Research
DISR	Department of Industry, Science and Resources
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
HGA	High Gain Antenna
ICSU	International Council of Science Unions
ISAS	Institute of Space and Astronautical Science, Ministry of Education and Science, Japan
MUSES	Mu-rocket Space Engineering spacecraft
NASA	National Aeronautics and Space Administration
NRC	National Research Council
OOSA	Office for Outer Space Affairs of the United Nations
OST	Outer Space Treaty
PPP	Panel on Planetary Protection
SCD	Soil Conservation District
SPS	Sanitary and Phytosanitary
SPS Agreement	WTO Agreement on the Application of Sanitary and Phytosanitary Measures
UN	United Nations
WTO	World Trade Organization

Cover image: *From ISAS MUSES-C Web site (Institute of Space and Astronautical Science (ISAS), {3})*

This quarantine review has been conducted in response to a formal access request from the Institute of Space and Astronautical Science (ISAS) of the Japanese government to bring a small amount (a few grams) of an asteroid sample into the Woomera Prohibited Area in South Australia as part of the MUSES-C space mission. The launch is expected in December 2002 and the recovery occurs around June 2007. The asteroid whose sample is returned is ‘1998 SF36’, which is identified and categorized into type-S, an undifferentiated metamorphosed asteroid, based on current Earth based information.

This paper contains the following sections:

- Introductory discussions of the background to this quarantine review, administration issues, Biosecurity Australia’s framework for quarantine policy, the international framework and Australia’s current policy for sample return from small solar system bodies
- An outline of the methodology for hazard categorisation
- An outline of Australia's international obligations and treaty commitments
- The results of risk assessment and risk management
- A position on the return of a surface sample from the asteroid 1998SF36 and a description of recommended quarantine conditions for the sample return.

Despite the perceived low risk and absence of trade implications, a quarantine review with public consultation has been undertaken because of the likely public interest and concern with the proposal. This quarantine review is being coordinated in consultation with Environment Australia.

A detailed risk assessment, entitled "*Evaluating the biological potential in samples returned from planetary satellites and small solar system bodies*" has already been undertaken by a Task Group on behalf of the Space Studies Board (SSB) of the United States (US) National Research Council (NRC). The NRC draws its members from the National Academy of Science, National Academy of Engineering, and the Institute of Medicine. The Task Group was comprised of a diverse group of highly qualified scientists. Because detailed risk analyses into sample returns from planetary satellites and small solar system bodies have already been undertaken, the primary role of this quarantine review has been to review and adapt these risk analyses, as appropriate, to ensure Australia's quarantine concerns are addressed.

Factors considered in this quarantine review include:

- whether liquid water, energy sources or organic matter which are necessary for life are present on the asteroid
- extremes of temperature and radiation exposure on the asteroid
- any evidence of life forms in meteorites
- the likelihood of an extraterrestrial life form surviving in an Earth environment.

Based on an analysis of these first three factors, Biosecurity Australia considers that the potential for a living entity to be present in a returned sample from a type S undifferentiated metamorphosed asteroid is extremely low to negligible but it cannot be concluded that the potential is zero.

Environmental exposure with the sample material at the landing site could occur if the sample container breaks open on impact (eg due to failure of the parachute to deploy). In the absence of sufficient information on the effects of introduced micro-organisms on established microbial communities, the possibility that an extraterrestrial anaerobic micro-organism, if one exists, could contaminate a suitable environment on Earth for growth cannot be discounted. However, Biosecurity Australia considers the potential to be very low.

Although Biosecurity Australia considers the overall risk of adverse effects from a returned sample from a type S undifferentiated metamorphosed asteroid to be extremely low to negligible, it must be acknowledged that more information is necessary to accurately determine the risks associated with return samples. Although available data will continue to expand over time, much of the information required will only be obtained by sample return missions. Until additional information is available, it is prudent to consider risk management procedures for return samples from small solar system bodies. Biosecurity Australia therefore recommends that, on re-entry, the returned sample and all associated equipment potentially contaminated with the sample be immediately placed into secure impervious containers, transported in a safe manner and exported from Australia to the ISAS laboratories. This is consistent with the ISAS proposal. International collaborative research has been proposed by ISAS for the sample. Once safety has been established by ISAS, reimportation for research purposes in non-secure facilities would be acceptable.

In the event of a breach of the sample container, all the soil around the capsule landing point that may potentially have been contaminated with the sample should be removed and sterilised (eg by kiln sterilisation) as proposed by ISAS. Machinery and other in-contact equipment used to collect and remove the soil should be treated with a broad spectrum sporicidal disinfectant or other appropriate treatment.

Environment Australia has also advised that the project is not a controlled action[1], provided the action takes place in a specified manner ie:

- prior to a commitment to re-entry, ISAS reviews any new scientific data or opinion in relation to the safety of the mission, and
- ground operations in Australia are in accordance with all relevant Australian government requirements, including compliance with any directions given by the Director of Quarantine or conditions applied to the quarantine import permit.

[1] An action is a *controlled action* under the *Environment Protection and Biodiversity Conservation Act 1999 (*EPBC Act) if approval under Part 9 is required for the purposes of a provision of Part 3 of the EPBC Act .

AUSTRALIA'S BIOSECURITY POLICY

Legislative framework

AFFA's objective is to adopt biosecurity policies that provide the health safeguards required by government policy in the least trade-restrictive way and that are, where appropriate, based on international standards. In developing and reviewing quarantine policies, disease risks associated with importations are analysed using a structured, transparent and science-based risk analysis process.

The *Quarantine Act* and its subordinate legislation, including the quarantine *Proclamation 1998*, are the legislative basis of human, animal and plant quarantine in Australia. The *Quarantine Amendment Act 1999,* which commenced in June/July 2000, is a major revision to the *Quarantine Act* to implement, *inter alia,* changes recommended in the report of the Australian Quarantine Review Committee (the AQRC).

Section 4 of the *Quarantine Act* defines the scope of quarantine as follows:

In this Act, quarantine includes, but is not limited to, measures:

- *for, or in relation to, the examination, exclusion, detention, observation, segregation, isolation, protection, treatment and regulation of vessels, installations, human beings, animals, plants or other goods or things*
- *having as their object the prevention or control of the introduction, establishment or spread of diseases or pests that will or could cause significant damage to human beings, animals, plants, other aspects of the environment or economic activities*

Quarantine Risk

The concept of level of quarantine risk has been introduced as the basis of quarantine decision-making. When making decisions under the *Quarantine Act*, decision-makers must have regard to the level of quarantine risk and must take prescribed actions to manage the risk if it is unacceptably high. For example, Section 44C of the *Quarantine Act* concerning the examination of goods on importation requires a quarantine officer to order the goods into quarantine if the officer is of the opinion that the level of quarantine risk is unacceptably high. Section 46A concerning approval of premises for the purpose of goods ordered into quarantine requires consideration of the level of quarantine risk, with regard to a number of matters including the proposed procedures and the construction and management of the premises, before approval may be given to a premises. Section 5D includes harm to the environment as a component of the level of quarantine risk:

Section 5D: level of quarantine risk

A reference in this Act to a level of quarantine risk is a reference to:

(a) the probability of:

> *(i) a disease or pest being introduced, established or spread in Australia or the Cocos Islands; and*
>
> *(ii) the disease or pest causing harm to human beings, animals, plants, other aspects of the environment, or economic activities; and*

(b) the probable extent of the harm.

Quarantine Proclamation

Subsection 13(1) of the *Quarantine Act* provides, among other things, that the Governor-General in Executive Council may, by proclamation, prohibit the importation into Australia of any articles or things likely to introduce, establish or spread any disease or pest affecting persons, animals or plants. The Governor-General may apply this power of prohibition generally or subject to any specified conditions or restrictions.

Quarantine Proclamation 1998 is the principal legal instrument used to control of the importation into Australia of goods of quarantine interest. A wide range of goods is specified in the *Quarantine Proclamation 1998* including animals, plants, animal and plant products, micro-organisms, and certain other goods which carry a high risk if uncontrolled importation is allowed, eg soil, water, vaccines, feeds.

For articles or things prohibited by proclamation, the Director of Animal and Plant Quarantine may permit entry of products on an unrestricted basis or subject to compliance with conditions, which are normally specified on a permit. A risk analysis provides the scientific and technical basis for biosecurity policies that determine whether an import may be permitted and, if so, the conditions to be applied.

The matters to be considered when deciding whether to issue a permit are set out in Section 70 of *Quarantine Proclamation 1998* as follows:

70 Things a Director of Quarantine must take into account when deciding whether to grant a permit for importation into Australia

> *(1) In deciding whether to grant a permit to import a thing into Australia or the Cocos Islands, or for the removal of a thing from the Protected Zone or the Torres Strait Special Quarantine Zone to the rest of Australia, a Director of Quarantine:*
>
> > *(a) must consider the level of quarantine risk if the permit were granted; and*
> >
> > *(b) must consider whether, if the permit were granted, the imposition of conditions on it would be necessary to limit the level of quarantine risk to one that is acceptably low; and*
> >
> > *(c) may take into account anything else that he or she knows that is relevant.*

The matters include the level of quarantine risk (see above), whether the imposition of conditions would be necessary to limit the quarantine risk to a level that would be acceptably low, and anything else known to the decision maker to be relevant.

Environment

Recent amendments to the *Quarantine Act* make explicit the responsibility of quarantine officers to consider impact on the environment when making decisions under the *Quarantine Act*. The scope of quarantine (Section 4) has been amended to include the environment, and the level of quarantine risk (Section 5D) also incorporates the environment. As shown below, environment has been broadly defined in Section 5 of the *Quarantine Act* to incorporate all aspects surrounding humans, whether natural or built:

> *Environment includes all aspects of the surroundings of human beings, whether natural surroundings or surroundings created by human beings themselves, and whether affecting them as individuals or in social groupings.*

When undertaking a risk analysis, the risk of harm to the environment must be fully considered to ensure that the quarantine policies developed reflect the Australian Government's approach to quarantine risk management and protection of the environment.

The *Quarantine Act*, Part IIA, requires the Director of Quarantine to refer certain decisions to the Environment Minister. Part IIA only applies to decisions made by the Director of Quarantine and decisions made using his/her delegation. Before making a decision under the *Quarantine Act*, the implementation of which is likely to result in a significant risk of harm to the environment, the Director of Quarantine must seek the views of the Environment Minister regarding the risk assessment process to be followed and subsequently the preliminary results of the risk assessment. The Director of Quarantine must take the advice of the Environment Minister into account and inform the Environment Minister of how this advice was taken into account. Part IIA also clarifies arrangements between quarantine decision-making and environment protection legislation, in particular the *Environment Protection and Biodiversity Conservation Act 1999*.

The risk assessments referred to in Part IIA are those undertaken when making decisions under the *Quarantine Act*, such as when as assessment is made of the level of quarantine risk and its acceptability. The Director of Quarantine's power to refer matters to the Environment Minister has been delegated to the Executive Director of AQIS and the Executive Managers of AQIS Operations and Market Access and Biosecurity. Routinely, Environment Australia is given the opportunity to comment on all proposals to develop new biosecurity policies.

This quarantine review conducted by Biosecurity Australia will focus primarily on risks associated with the introduction of pests and diseases. However, because of both the unusual and unique nature of the MUSES-C proposal, tight timeframe based on the intended launch in 2002 and the need by Environment Australia to consider environmental risks other than the introduction of diseases, this quarantine review by Biosecurity Australia has been coordinated in consultation with Environment Australia.

Environment Australia has advised that, on 14 May 2002 the delegate of the Minister for the Environment and Heritage decided under s75 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) that the action is not a controlled action provided it is carried out in a particular manner, as follows:

> "***Manner in which the proposed action is to be taken***
>
> *ISAS will, prior to commitment to earth re-entry and in consultation with relevant internationally recognised experts, conduct a review of any new scientific data or opinion available (including data obtained during the MUSES-C mission to that point) in order to determine whether the mission should be reclassified to 'restricted Earth return' status. The sample canister will not be returned to Australian territory if the weight of new scientific evidence or opinion is that 'restricted Earth return' status is warranted.*

Ground operations on Australian soil, including recovery and implementation of any contingency plans and requirements, will be in accordance with the following:

- *license conditions or directions imposed by the Space Licensing and Safety Office, for protection of the environment, pursuant to the Space Activities Act 1998 and the Space Activities Regulations 2002;*
- *any directions given to ISAS by the Director of Quarantine or conditions that may be applied to an import permit under the Quarantine Act 1908 and its subordinate legislation for protection of the environment;*
- *compliance with undertakings for protection of the environment contained in any Memorandum of Understanding between the Governments of Australia and Japan related to the MUSES-C mission;*
- *any direction or instruction for protection of the environment issued by the Department of Defence in regard to activities potentially affecting the Woomera Prohibited Area; and*
- *measures and undertakings stated in the referral received 4 January 2002 for protection of the environment.*"

In the event that ISAS is not able to carry out the mission in the manner described, ISAS will inform the Minister for the Environment and Heritage so that further consideration can be given to the application of the provisions of the EPBC Act to the MUSES-C project. Also, in accordance with regulation 501(b) of the Space Activities Regulations 2001, ISAS will prepare and submit an adequate environmental management plan for the MUSES-C mission.

Policy framework

The primary purpose of quarantine is to facilitate the movement of goods and people into Australia while protecting Australia from the entry, establishment and spread of unwanted pests and diseases which could damage our way of life, agriculture and the environment. Such pests and diseases may threaten human health, damage crops, livestock and ecosystems, reduce productivity, require expensive control measures and affect the market's acceptance of affected or related commodities.

Successive Australian Governments have maintained a highly conservative but not a zero-risk approach to the management of quarantine risks, evident in the strictness of all quarantine related activities, including policies with regard to imported commodities, procedures at the border and operations against incursions of pests and diseases.

Recent inquiries into Australia's quarantine regime have recognised that it is impossible in practice to operate a zero-risk quarantine regime. In 1979, the Senate Standing Committee on Natural Resources stressed that there is no such thing as a zero risk quarantine policy, which it believed should be better described as "*... scientific evaluation of acceptable risk ...*". In 1988, the Lindsay Review of Australian quarantine concluded that "*... a no risk policy is untenable and undesirable and should be formally rejected ...*". In 1996, the Senate Rural and Regional Affairs and Transport Committee was of the view that a zero risk approach was unrealistic and untenable, and that its currency only demonstrated that the concepts of risk assessment or risk management were widely misunderstood. These themes were repeated in the 1996 report of the AQRC, chaired by Professor Nairn. In the Government's 1997 response to the report, the Government confirmed a managed risk approach. Australia will continue to be very averse to accepting quarantine risks. Products will only be permitted entry if any risks can be reduced to very low levels which can be managed with confidence.

In keeping with the scope of the *Quarantine Act* and Australia's international obligations, only factors relevant to the evaluation of quarantine risk (ie the risk associated with the entry, establishment and spread of unwanted pests and diseases) are considered in this quarantine review.

THE WTO

The *SPS Agreement* applies to measures designed to protect human, animal and plant life and health from certain things, or a country from pests, which may directly or indirectly affect international trade, and reaffirms the right, subject to conditions, of WTO Member countries to have such measures in place. Sanitary (human and animal health) and phytosanitary (plant health) measures apply to trade in or movement of animal and plant based products produced within a country, as well as to products imported from or exported to other countries.

The MUSES-C project is one of international cooperation in the interests of the advancement of science. It has no significant trade implications other than the generation of international goodwill. However, for the purposes of the *SPS Agreement,* Australia has the right to apply appropriate SPS measures to the proposed importation to protect itself from possible entry, establishment or spread of disease organisms.

METHODOLOGY

OVERVIEW OF THE APPROACH TO QUARANTINE RISK

In line with Biosecurity Australia's risk analysis methodology, this quarantine review for sample return is based on the following procedures:

- Hazard identification
- Risk assessment, incorporating;
    - Release assessment
    - Exposure assessment
    - Consequence assessment
    - Risk estimation
- Risk management
- Risk communication[2]

METHOD FOR HAZARD IDENTIFICATION

- Hazard identification is a classification step, with the purpose of identifying pathogenic agents (or clearly identified strains of pathogenic agents) that could be associated with the importation of a commodity. Agents thus classified are termed 'potential hazards'.

However, disease agents, if present on the asteroid, may be substantially different from those which occur on Earth and therefore, generating a comprehensive and specific list of disease agents likely to be relevant to sample returns is both impractical and irrelevant. Rather, this hazard identification first addresses the likelihood of the presence of various types of micro-organisms and other agents and the likelihood these could be harmful.

[2] Risk communication is an iterative process carried out in accordance with AFFA's risk analysis process.

RETURN OF SURFACE SAMPLES FROM ASTEROID 1998SF36

BACKGROUND

A meeting was held on 23 August 2001 by the Space Policy section of the Department of Industry, Science and Resources (DISR) to discuss a proposal by the Institute of Space and Astronautical Science (ISAS), Ministry of Education and Science, Japan, on the potential use of the Woomera area for the return of an asteroid sample carried by the MUSES-C re-entry capsule. Present at the meeting were representatives from ISAS, BAE SYSTEMS, DISR, Biosecurity Australia and Environment Australia.

THE PROPOSAL

A formal access request was received from ISAS of the Japanese Government in December 2001 to bring a small amount of an asteroid sample in the Woomera Prohibited Area in Australia as part of the MUSES-C mission.

ISAS proposes to launch an interplanetary spacecraft with the objective of returning a small sample of an asteroid back to the Earth. ISAS proposes to use the Woomera Prohibited Area for the recovery of the sample contained in a sealed re-entry capsule, which descends suspended by a parachute. The launch is expected in December 2002 and the recovery occurs around June 2007. The asteroid from which the sample is to be returned is 1998 SF36, which is identified and categorized into type-S, an undifferentiated asteroid, which is believed to be made of olivine rich silicate.

The Japanese Government is seeking Australian quarantine approval for the sample recovery capsule before launch in 2002. It has submitted, in parallel with the access request, a referral form to Environment Australia.

The re-entry will occur between the end of May and the beginning of June in 2007. The exact date will be specified very accurately (to the hour), three months prior to the re-entry. The MUSES-C project originally planned for the sample recovery to be in the US. However, the target asteroid was changed due to technical reasons with the launch vehicle, and the recovery scenario had to be amended, requiring recovery in Australia due to the amended trajectory.

The sample is contained in a special canister, which is about 6cm long and 3cm in diameter. The canister is referred to as a sample catcher, which is pushed and tightly sealed into a container aboard the re-entry capsule. The container is sealed in vacuum condition and sealed by double metal o-rings. The re-entry capsule weighs about 20kg and its diameter is 400mm.

The mother spacecraft jettisons the capsule nominally ten hours before re-entry. It is given a low spin of several revolutions per minute. The parachute is deployed at an altitude of about 10 km. The capsule surface is made of forward and aft heat-shield shells, which are ejected when the chute is deployed. The shells passively fall down to the ground at several tens of metres per second. The parachute suspends the sample container as well as the beacon transmitter. The touch-down velocity is around ten meters per second. The chute is cut off several minutes after it lands to prevent it from being pulled by the wind. The beacon transmitter radiates the radio signal for about two days.

The proposed landing dispersion area is approximately 100 km in an east-west direction and 40km north-to-south. The capsule will be localised by radio direction finding antennae and potentially optical/infrared tracking and radar. The capsule jettison occurs while the spacecraft is visible and under operational control from the Japanese tracking station. Last minute navigation and other information is received on the ground for the final status confirmation. Since the landing dispersion is large, the recovery requires an area with few residents such as the Woomera Prohibited Area which is managed by the Department of Defence. It is possible to estimate re-entry to within twenty minutes at one week prior to the recovery and then more accurately the closer to re-entry.

The mother spacecraft re-enters into atmosphere above the Woomera area. ISA has demonstrated by analysis that all of the mother spacecraft is burnt-up/ablated during the very high speed of re-entry. No radioactive material is aboard. No hazardous material is left aboard the capsule except a lithium battery that is removed by the ISAS personnel immediately on recovery. The jettisoned heat shield shells are made of carbon fibre reinforced plastic (CFRP) and are not hazardous. Although not equipped with active beacon transmitters, ISAS will search for the heat shield shells to remove them from the Woomera area. In case the sample container is broken, ISAS will remove any soil that may have potentially some sample material around the capsule’s landing point and ISAS will restore the soil to a safe condition. The potential for rupture and the proposed clean-up is discussed in detail in the exposure assessment and risk management sections.

ADMINISTRATION

Timetable

Although re-entry is not until 2007, a commitment to the landing zone is required by ISAS well before launch in Nov/Dec 2002. This will require quarantine approval as soon as possible, preferably no later than July 2002.

Scope

This quarantine review considers quarantine risks that may be associated with the return (importation) to Australia of a sample from the 1998SF36 asteroid. In this quarantine review, the return sample is defined as all material collected from the asteroid as well as the container, re-entry vehicle and associated equipment and material which returns from the asteroid.

Despite the perceived low risk and absence of trade implications, a quarantine review with public consultation is being undertaken because of the likely public interest and concern with the proposal. Due to the unique nature of the proposal, the time frame involved and the extensive amount of work already undertaken in the field of risk analysis for sample return from small planetary bodies, this quarantine review will primarily précis assessments already undertaken, discuss and, if necessary, expand on each relevant issue and either endorse or reject recommendations as determined appropriate.

Space Studies Board (SSB) Task Group

A detailed risk assessment, entitled " Evaluating the biological potential in samples returned from planetary satellites and small solar system bodies" has already been undertaken by a Task Group on behalf of the Space Studies Board (SSB) of the US National Research Council (NRC). The NRC draws its members from the National Academy of Science, National Academy of Engineering and the Institute of Medicine. The Task Group was comprised of a diverse group of highly qualified scientists.

This assessment was the subject of a Committee on Space Research (COSPAR) workshop in April 2002 and COSPAR endorsement of the final assessment and recommendations is expected at its international conference in October 2002. Because detailed risk analyses into sample returns from planetary satellites and small solar system bodies have already been undertaken, the primary role of this quarantine review has been to review and adapt these risk analyses, as appropriate, to ensure Australia's quarantine concerns are addressed. As part of the process, additional technical input will be sought on this quarantine review document.

CURRENT QUARANTINE POLICY FOR THE RETURN OF SAMPLES FROM OUTER SPACE

International policy

The Committee on the Peaceful Uses of Outer Space (COPUOS) was set up by the United Nations (UN) General Assembly in 1959 to review the scope of international cooperation in peaceful uses of outer space, to devise programmes in this field to be undertaken under UN auspices, to encourage continued research and the dissemination of information on outer space matters, and to study legal problems arising from the exploration of outer space. Both Australia and Japan are member states in the Committee. COPUOS is the only international forum for the development of international space law. The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (the "Outer Space Treaty" (OST) was adopted by the General Assembly in its resolution 2222 (XXI)), and entered into force in October 1967 (United Nations General Assembly, 1967{17}). As of 1 February 2001, it has 96 ratifications and 27 signatures (United Nations Committee on the Peaceful Uses of Outer Space and its Subcommittees, Jan 2001{16}).

The international legal principles in the OST and 4 other international treaties governing space-related activities provide for non-appropriation of outer space by any one country, arms control, the freedom of exploration, liability for damage caused by space objects, the safety and rescue of spacecraft and astronauts, the prevention of harmful interference with space activities and the environment, the notification and registration of space activities, scientific investigation and the exploitation of natural resources in outer space and the settlement of disputes.

Australia and Japan have both ratified the 1967 Outer Space Treaty (OST). Article IX of the OST states that "*Parties to the Treaty to pursue studies of outer space, including the moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth, resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose*".

The International Council of Science Unions (ICSU) is a non-governmental organization, founded in 1931 to bring together scientists in international scientific endeavour. It comprises 98 multi-disciplinary National Scientific Members (scientific research councils or science academies) and 26 international, single-discipline scientific unions to provide a wide spectrum of scientific expertise enabling members to address major international, interdisciplinary issues. Funding is provided primarily by members and the United Nations. The ICSU Committee on Space Research (COSPAR) is also a nongovernmental organization that consults with the UN on planetary protection issues, particularly with respect to the provisions of the 1967 Space Treaty.

COSPAR comprises several scientific commissions and panels. Historically, COSPAR's Scientific Commission F which is concerned with "life sciences as related to space" is the principal Commission concerned with planetary protection[3]. Recently, COSPAR has supplemented Commission F's role with the formation of a Panel on Planetary Protection that has been chartered to shepherd planetary protection policy specifically. COSPAR policy is proposed by the Panel in collaboration with Scientific Commission F and adopted by the COSPAR Council which is made up of commission representatives and the representatives of national members including Australia and international scientific unions. National Aeronautics and Space Administration (NASA) policy is that it will not participate in international missions unless each international partner agrees to follow COSPAR planetary protection policy. NASA has established planetary protection provisions for robotic extraterrestrial missions (NASA, 1999{5}).

The following statement was made at a COSPAR workshop in April 2002: "*Upon the request of ISAS and Environment Australia, the COSPAR Workshop on Planetary Protection considered the categorization of the MUSES-C mission, and concurred with the recommendations of the NASA Planetary Protection Advisory Committee, agreeing that the Muses-C mission's asteroid target (1998SF38) meets the US National Research Council Space Studies Board classification as a body from which a Category V mission with "unrestricted Earth-return" is warranted. The Workshop participants furthermore acknowledged that the procedures undertaken in this review comply with the small-body sample return policy developed for COSPAR during the Workshop.*"

Domestic quarantine policy

Under Section 4, Scope of quarantine, of the *Quarantine Act 1908*, quarantine includes appropriate measures applied to humans, animals, plants and things having as their object the prevention or control of the introduction, establishment or spread of diseases or pests that will or could cause significant damage to humans, animals, plants, the environment or economic activities. In deciding whether to grant an import permit, the Director of Quarantine must consider the level of quarantine risk, including possible conditions necessary to limit the level of quarantine risk to one that is acceptably low.

The Commonwealth Government is responsible for regulating the movement of humans, animals, plants, micro-organisms and their products into and out of Australia. The State/Territory Governments have primary responsibility for human, animal and plant health controls within Australia. Legislation relating to resource management or animal or plant health may be used by State/Territory Government agencies to control interstate movement of animals and their products.

[3] Planetary protection is the term given to the policies and practices that protect other solar system bodies (e.g., planets, moons, asteroids, and comets) from Earth life, and that protect the Earth from life that may be brought back from other solar system bodies.

A Quarantine Entry and Import Permit is not required for the importation of minimal risk minerals, metal ores and related materials. A Quarantine Entry and Import Permit is required for soil and related soil material including surface materials such as earth, sand, river gravels or pebbles, soil-like surface minerals, stream sediments, old tailings dumped from mining areas, powdered samples without evidence of origin and generally samples obtained from the upper 2 meters of Earth's surface.

Meteorites which land on Earth are typically solid rock, devoid of sand or soil and the outside of which have been heated to extreme temperatures on entry. It is therefore reasonable that these be treated as minimal risk minerals. While there is evidence that asteroid 1998 SF36 has a olivine and pyroxene content, the exact nature of the surface of the asteroid from which the sample will be taken is unknown. The risk associated with return samples will vary markedly between the various asteroid types, planets and other planetary bodies. Biosecurity Australia therefore considers it appropriate that a risk assessment be undertaken and Quarantine Entry and Import Permit be required for all return samples.

HAZARD IDENTIFICATION

Introduction

The potential risks associated with sample return need to be evaluated and risk measures undertaken if appropriate. Planetary protection policy seeks to preserve natural conditions on planets and other bodies in the solar system while also protecting Earth and its biosphere from potential extraterrestrial sources of contamination.

Concerns about potential risks from returned extraterrestrial materials were initially raised with the return of lunar samples during the Apollo program. The National Research Council's (NRC) Space Studies Board (SSB) produced a paper, *Mars Sample Return: Issues and Recommendations* (Space Studies Board (National Research Council), 1997{8}) assessing the possibility of a viable entity in a sample returned from Mars as well as possible effects on Earth's biosphere. The SSB is the primary advisor to NASA for planetary protection policy. The paper concluded that *"the potential for including a living entity in a sample returned from Mars is judged to be low, especially if the sample is returned from a site that has not been specifically targeted as a possible oasis. The potential for returning an organism that could grow and multiply in the terrestrial environment is lower still. If an organism were returned that could survive on Earth, the potential for large-scale ecological or pathogenic effects still would be low. Any organism that could survive in Earth's environment would meet intense competition from well-adapted terrestrial organisms that occupy their habitats to the limits of available resources. It is especially unlikely that putative martian organisms could be agents of infectious disease. Such a capability requires specific adaptations, for which there would be no selection pressure on Mars, to overcome the elaborate defenses against invasion possessed by terrestrial organisms.*

There are large uncertainties associated with these assessments, however, and the risk of potentially harmful effects is not zero."

A SSB Task Group has subsequently released a report, *Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies* *(Space Studies Board (National Research Council), 1998{11})* which considers the potential for samples returned to Earth from small solar system bodies to contain harmful living entities. The SSB task group focused on the following topics:

"1. The possibility that, at some time in the past, life originated on a body from which a sample might be taken, or that life was transported there from elsewhere in the solar system;

2. The possibility that life still exists on the body either in active or in reactivatable form; and

3. The potential hazard to terrestrial ecosystems from extraterrestrial life if it exists in a returned sample."

The task group considered what is known about the origin of life on Earth, the conditions for the preservation of metabolically active organisms in a terrestrial environment, and the somewhat different conditions needed to preserve living organisms in an inactive form. By generalising from terrestrial experience and assuming that all forms of life will be composed of organic compounds and dependent on organic chemistry, the task group identified six parameters relevant to assessment of the potential for presence of a biological entity in returned samples:

"1. Liquid water*: Liquid water may safely be considered a requirement for life on small solar system bodies, because the chemistry on which life is based must take place in solution, and there is no other plausible solvent.*

2. Energy sources*: A source of energy to support the origin and continuation of life in any environment is a thermodynamic necessity. For extraterrestrial environments, the energy sources are more likely to be geochemical than photosynthetic.*

3. Organic compounds*: Chemical building blocks for organic polymers must be available.*

4. Temperature*: The temperature limits for the survival of metabolically active cells (160°C) at 1 atm are likely to apply to extraterrestrial organisms also unless their biochemistry does not depend on the formation of amide, ester, or phosphodiester bonds.*

5. Radiation intensity*: Extraterrestrial biopolymers are unlikely to differ greatly from terrestrial biopolymers with respect to radiation sensitivity.*

6. Comparison to natural influx to Earth*: Earth receives a natural influx of material (in the form of dust and meteorites) from other bodies in the solar system. Some material may be delivered in ways that shield it from sterilizing temperatures or radiation. "*

Based on these six parameters, the task group formulated a series of questions to assess the potential for a biological entity to be present in or on samples returned from planetary satellites, asteroids, comets, and cosmic dust and subsequent implications for sample containment and handling. Biosecurity Australia endorses the use of these 6 parameters as an appropriate indication of this potential.

Extremophilic terrestrial life forms

The SSB Task Group report examined current knowledge of early Earth as a model for the origins of self-replicating life forms (Space Studies Board (National Research Council), 1998{10}). The report assumes that all organisms, including animals, plants and microbial species, have their common ancestral roots within these earliest life forms. Without exception, all known life is carbon based. Every documented terrestrial cellular life form is a self-replicating entity that has nucleic acid polymers coding for proteins providing its genetic information. Biologically active systems require water, carbon, nitrogen, phosphate, sulphur, various metals, and a source of energy (from either solar radiation or chemosynthetic processes).

Viruses and novel agents such as prions were not discussed by the report. These are also carbon based but are not self-replicating. They require the presence of a self-replicating life form for replication. Viruses consist of a nucleic acid genome surrounded by a protective coat of protein and, for some viruses, a lipid envelope. Viruses infect animals, plants, bacteria and other microbes.

Prions are infectious proteins thought to cause a group of fatal neuro-degenerative diseases. These prion diseases present as either genetic, infectious or sporadic disorders, all involving modification of the prion protein (PrP). Examples of transmissible spongiform encephalopathies (TSEs) in animals include bovine spongiform encephalopathy (BSE), scrapie in sheep, chronic wasting disease of elk and transmissible mink encephalopathy. In humans, TSEs include Creutzfeldt-Jakob disease (CJD), Kuru, Gerstmann-Sträussler-Scheinker syndrome (GSS) and fatal familial insomnia (FFI). Prions are devoid of any nuclear material and are comprised entirely of a modified protein (PrP^{sc}). The normal cellular protein (PrP^{c}), which is characterised by a structure of 4 helixes (α-helixes), is converted to PrP^{sc} during which 2 of the helixes are converted to linear structures (β-sheets). It appears that PrP^{sc} acts as a template upon which PrP^{c} is refolded into PrP^{sc}. This process may be facilitated by another protein which has yet to be described (Prusiner, 1998{6}).

Viruses and prions are unlikely to exist without the presence of a self-replicating life form and will only need to be considered if there is a significant possibility that life exists or has previously existed on the asteroid.

According to the SSB Task Group's report, the conditions that nurtured early self-replicating systems and their transition into microbial cells are speculative. Liquid water, utilisable free energy and an acceptable environmental temperature are necessities for life to originate. The modes of information storage, retrieval, and processing and their enzymatic activity of extraterrestrial biosystems, if they exist, may not be identical to those on Earth.

Microbes can adapt to a much wider range of environmental conditions than multicellular organisms and are therefore more likely to retain viability on small solar system bodies. Microbes have been found in many extreme environments that would be lethal for other life forms.

Microbes with active DNA repair mechanisms or a protective layer of material are more likely to survive ultraviolet or ionising radiation than cells without equivalent capabilities. Many microbes are capable of becoming metabolically inactive (dormant) spores or other cells which remain viable at suboptimal or freezing temperatures and/or in a desiccated state. These are capable of returning to an active state under favourable environmental conditions.

Examples of extreme environments include:

Psychrophile bacteria which are capable of growth at temperatures lower than 0°C. Hyperthermophiles may grow at 90°C or above and growth up to 113°C has been reported. Anaerobes grow in the absence of oxygen while acidophiles and alkalophiles are capable of growth at extreme pH values (ie < 2 or >10). Extreme halophiles require high concentrations of salt. A number of deep-sea bacteria are called barophilic growing optimally under pressure.

The nutrients used by microbes may also vary widely. Most are capable of utilising carbon dioxide as a source of carbon however some derive energy from chemical compounds and use organic or, in some cases, inorganic compounds as a source of electrons.

The SSB Task Group report states that *"The inability to culture many of the micro-organisms known to exist on Earth is of profound importance in estimating the possibility of micro-organisms* *existing and/or surviving on small solar system bodies. Extremophiles not yet cultured certainly exist on Earth, and the ability of those that have been cultured to survive hostile conditions has already established new limits for the range of environmental conditions that can support viable organisms. Lack of knowledge about extremophiles on Earth is a significant source of uncertainty when assessing the probability of biological contamination of Earth by organisms that may be present in samples returned from small solar system bodies."*

Factors influencing the survival of organisms include their physical and chemical environments, available energy sources and chemical nutrients. Extremes of temperatures and elevated levels of ionising radiation dictate the environmental limits for survival. The documented range of temperatures at which microbial growth is possible is -10°C to 113°C although the absolute limits have not yet been determined. Unless protected, micro-organisms on small solar system bodies would be exposed to Ultra Violet and ionising radiation. The dose at which radiation is lethal or sublethal will depend on intrinsic cellular characteristics such as ability to sporulate, the capacity to synthesize protective pigments, and the efficiency of DNA repair mechanisms, since DNA is the primary site of radiation damage.

Most micro-organisms are reasonably sensitive to gamma radiation however bacterial spores and certain other species (eg *Deinococcus* spp.) are much more resistant. Little is known about the mechanisms of radiation resistance of other groups of micro-organisms that live near natural sources of radiation.

Although all micro-organisms require water, they vary widely in their ability to grow and survive at different levels of water activity (a_w) and in their tolerance to desiccation. Survival times vary considerably but may be thousands of years for spores and, for endolithic bacteria, to possibly millions of years in permafrost.

Although solar energy is available in many extraterrestrial environments, its use by micro-organisms requires liquid water and perhaps atmospheres capable of filtering out harmful radiation while allowing beneficial wavelengths. Therefore, micro-organisms on small solar system bodies would most likely depend on geochemical energy sources. As aerobic environments are not likely to be present on small solar system bodies, micro-organisms most likely to occur on small solar system bodies would be anaerobic chemotrophs. According to the SSB Task Group report, examples of such extremeophiles include the following and, with the exception of acetogens, have been isolated from volcanic or submarine hydrothermal vent environments:

"1. Methanogens (CO_2 + H_2 (CH_4);

2. Acetogens (H_2, CO_2, CO, HCOOH, CH_3OH, etc. (CH_3COOH);

3. Iron-reducers (acetate, fatty acids, aromatics + Fe [III] (CO_2 + Fe [II]);

4. Anaerobic methane oxidizers;

5. Heterotrophic, CO_2-fixing sulfur reducers (sulfur, sulfate and thiosulfate); and

6. Fermentors (assuming a source of appropriate carbon substrates formed abiotically or from decomposition of carbon dioxide-fixing micro-organisms)."

The SSB Task Group report also states that "*Chemolithoautotrophs (organisms that use inorganic forms of energy and carbon) could be the dominant microbial forms in some extraterrestrial environments. The recent description of subterranean lithoautotrophic microbial ecosystems (SLIMEs) in deep subsurface basalts points to a microbial community that is not dependent on organic carbon or energy sources derived from photosynthesis (Stevens and McKinley, 1995{14}).*

This community subsists on H_2 that is formed from the abiotic interaction of basalt with water. It derives its energy from metals, sulfur, or hydrogen and fixes CO_2. SLIME may be the closest analog for life in the subsurface lithology of Mars and similar solar system bodies."

Micro-organisms may become dormant (ie a suspended states of metabolic activity) to survive extreme environmental conditions. However other factors such as ionising radiation may have a detrimental effect. Although there are reports of quiescent eukaryotic and prokaryotic organisms having survived for thousands of years in preserved tissues or in permafrost, the survival capabilities of micro-organisms have not been studied rigorously. This is particularly true for micro-organisms that can utilize very low concentrations of organic nutrients or inorganic energy sources and microbes that inhabit the most extreme environments on Earth. Very low levels of water activity and/or reduced temperatures enhance survival in a dormant state. Dehydration suspends enzymatic activities, including the destructive activities of proteases, hydrolases, and nucleases. Metabolically inactive micro-organisms do not have the capacity to repair the devastating effects of exposure to relatively low levels of radiation or damage from the formation of free radicals however, when metabolic activity is regained, the mechanism for repair of such detrimental effects may be reactivated.

Natural influx from asteroids and other small bodies

To assist in placing the potential risk of returning samples from asteroids into perspective, it is useful to assess the material arriving on Earth naturally as meteorites. Earth receives a considerable amount of material from space, the largest volume of which is due to rare impacts by large bodies. However, most meteorites are relatively small objects derived from the asteroids in the asteroid belt. Many meteorites have evidence of damage by impacts. However, most meteoritic material is relatively undamaged. To date, there has been no evidence of life forms on such material.

Cross-contamination of asteroids with interplanetary debris and due to impacts with other asteroids means that small fractions of meteorites could have been from other bodies including those from which Earth does not usually receive meteorites directly.

When meteorites penetrate through Earth's atmosphere, the effect will depend on both the impact angle and velocity and the size and nature of the material. Large asteroids penetrate the atmosphere and land at very high velocities causing an explosion crater whereas smaller objects may burn up in the atmosphere. Interplanetary dust particles arriving at lower velocities may survive and settle to Earth relatively intact.

For some planetary satellites and small bodies, the uncertainty associated with cross-contamination reduced the degree of confidence in the SSB task group's assessment of the inherent safety of a sample return from that body.

Questions appropriate for assessing the biological potential of small bodies

The SSB task group developed a set of questions (Space Studies Board (National Research Council), 1998{12}) to aid in identifying whether samples from small bodies have biological potential and require containment. The questions are based on the review's opinion that life on Earth and the survival of metabolically active cells requires liquid water, an accessible energy source, temperatures not exceeding approximately 160°C, carbonaceous material, and shielding from high-intensity or long-term exposure to ionising radiation or Ultra Violet flux. Dormant life form requirements are less stringent, being able to survive in nearly completely dehydrated states, tolerate higher levels of ionising radiation and the complete absence of organic compounds and sources of energy.

The SSB task group concluded that "*although there is a low likelihood of a viable anaerobic microorganism surviving transport through space and finding a suitable anaerobic habitat on Earth, growth in a suitable habitat if found might be possible. This conclusion is necessary because of our current lack of information about anaerobic environments on Earth that may be analogous to environments on other solar bodies, and the likelihood that the metabolic properties of such an extraterrestrial anaerobe would resemble an Earth anaerobe from a similar environment.* "

The questions, formulated by the SSB Task Group, for assessing the biological potential are as follows:

"*1. Does the preponderance of scientific evidence indicate that there was never liquid water in or on the target body?*

2. Does the preponderance of scientific evidence indicate that metabolically useful energy sources were never present?

3. Does the preponderance of scientific evidence indicate that there was never sufficient organic matter (or CO_2 or carbonates and an appropriate source of reducing equivalents) in or on the target body to support life?

4. Does the preponderance of scientific evidence indicate that subsequent to the disappearance of liquid water, the target body has been subjected to extreme temperatures (i.e., >160°C)?

5. Does the preponderance of scientific evidence indicate that there is or was sufficient radiation for biological sterilization of terrestrial life forms?

6. Does the preponderance of scientific evidence indicate that there has been a natural influx to Earth, e.g., via meteorites, of material equivalent to a sample returned from the target body? "

The SSB Task Group report uses the term "preponderance of scientific evidence" to connote a non-quantitative level of evidence compelling enough to research scientists in the field to support an informed judgment. A "no" answer must be returned to all the questions for containment procedures to be considered necessary. A "yes" answer to any question implies that no special containment is required beyond that needed for scientific purposes.

The Source of the sample (Asteroid 1998 SF36)

The asteroid from which the sample is to be returned is 1998 SF36 which has been identified and characterised, using Earth base spectral analysis, as a type S undifferentiated metamorphosed asteroid. Its size is approximately 300x600 metres. It is composed of reddened ordinary chondrite material with spectral characteristics of olivine and pyroxene content. The infrared spectral data indicates that there is no water and that the surface temperature when it is at the perihelion distance is about 410 Kelvin (137^{o}C) at its sub-solar point (Binzel et al. {2}).

Asteroids, like comets, are the remnant population of planetesimals—those small primordial bodies from which the planets accumulated. As defined by the SSB Task Group's review, type S undifferentiated metamorphosed asteroids are ordinary chondrites with a reflectance spectrum of moderate albedo, reddish in visible, weak to moderate absorption near 1µm and 2 µm.

Information on the early history of asteroids and the association between the various types of asteroids and meteorites is uncertain. It is, however, thought that a planet never accreted in the asteroid belt because of the influence of Jupiter. Large gaps in the distribution of asteroids may be where planetesimals once existed but no longer do, owing to resonant perturbations by Jupiter. Some depletion of the asteroids may also have occurred due to collisional fragmentation. Evidence of this collisional process can be seen in some meteorites whose properties reflect the collisions that break, shatter, and weld together the asteroidal rocks.

The SSB Task Group review suggests that most asteroids contain low-level radiation sufficient to have sterilised remnant life even in the buried, shielded portions of asteroids. However strongly differentiated objects depleted in radioactive elements or portions of undifferentiated objects that contain pockets of ice may be an exception.

Refer to the SSB Task Group review for a more detailed discussion of the different types of asteroids and meteorites, their origin and composition (Space Studies Board (National Research Council), 1998{9}).

Undifferentiated, metamorphosed asteroids such as 1998 SF36 are considered to have been heated to temperatures at which biological materials could not survive although these temperatures are probably less than 1,000 K (727^{o}C) as minerals did not segregate macroscopically. These asteroid types are also dehydrated although may have been hydrated at some time in the past. Ordinary chondrites are the most common meteorites reaching Earth and are considered to be fragments of such asteroids. Most ordinary chondrites exhibit the effects of prolonged heating to temperatures, possibly by radionuclide decay, sufficient to cause metamorphism and in some cases, partial melting.

Potential for a living entity to be in or on samples returned from asteroids

In determining the biological potential for S-type asteroids, the SSB task Group made the following determinations (Space Studies Board (National Research Council), 1998{9}):

"1. Does the preponderance of scientific evidence indicate that there was never liquid water in or on the target body?

> *…A minor fraction of S-type asteroids may have experienced a transient episode of aqueous activity, but the great majority of S-types have never seen liquid water. …*

2. Does the preponderance of scientific evidence indicate that metabolically useful energy sources were never present?

> *There is no evidence one way or another regarding the presence of metabolically useful energy sources in other asteroid types.*
>
> (Note however that the MUSES-C sample will be collected from an area of the asteroid where there would be a sufficient amount of light to support photosynthesis)

3. Does the preponderance of scientific evidence indicate that there was never sufficient organic matter (or CO_2 or carbonates and an appropriate source of reducing equivalents)[4] in or on the target body to support life?

> *In most asteroids (especially C-types), there was some (or even an abundance) of organic matter. In others, especially the metamorphosed and differentiated asteroids, there was not.*

4. Does the preponderance of scientific evidence indicate that subsequent to the disappearance of liquid water, the target body has been subjected to extreme temperatures (i.e., >160 °C)?

> *…..In general, there has been no source of sterilizing heat to raise the temperatures of most asteroid materials since primordial epochs, except for the localized heating due to impacts.*

5. Does the preponderance of scientific evidence indicate that there is or was sufficient radiation for biological sterilization of terrestrial life forms?

> *The interiors of undifferentiated asteroids would have experienced sterilizing doses of radiation from the decay of natural radionuclides during the 4.5 Gyr since cessation of aqueous activity. (The exception is the possibility that localized pockets of ice might have shielded some materials from such radiation within C-type, but not metamorphosed, asteroids). ……*

6. Does the preponderance of scientific evidence indicate the natural influx to Earth, e.g., via meteorites, of material equivalent to a sample returned from the target body?

> *Meteorites and interplanetary dust particles (IDPs) have delivered samples of many asteroids to Earth. Some of those meteorites (although virtually no IDPs) would have been protected from sterilizing doses of radiation from galactic and solar cosmic rays while in transit to Earth. Therefore, some C-type material certainly regularly arrives on Earth unsterilized and has not been observed to have adverse effects. Whether or not the C-type material so received is representative of a particular target body, however, is uncertain.* "
>
> According to Dr Alex Bevan, Meteorite Curator of the Western Australian Museum, the average flux of meteorites to the Earth, calculated from desert accumulations, is 82 falls per 1 million sq km per year of meteorites greater than 10 grams. This is in excellent agreement with the modern flux calculated from the Canadian MORP camera network of 83 falls >10 grams per million sq. km per year and suggests that the flux has not changed significantly for around 50 thousand years. The data from MORP indicate around 13800 falls of at least 100 gms each on the Earth's land surface each year. Around 80% of the constitution of the flux is ordinary chondrite - 86 % of the flux accounts for all chondritis. Dr Alex Bevan has calculated this to represent more than 500 chondritic meteorites (around ten a week) of significant weight falling on Australia each year (Bevan, {1}).
>
> According to the Report of the Australian Academy of Science Subcommittee on the draft quarantine review of the MUSES-C project (Taylor, 2002{15}), "*meteorites encounter the atmosphere of the Earth at a minimum velocity of 11.2 km/sec. During their passage through the atmosphere, the outside of the body melts and is ablated, so that when the meteorite lands, it is covered with a thin (millimeter) fusion crust. Because of the brief time (seconds) of passage through the atmosphere and the low thermal conductivity of the rocky meteorite, the heating caused by atmospheric entry does not penetrate beyond a millimeter or so into the meteorite. The meteorite is sometimes broken on impact with the Earth, so that the unheated interior is exposed. Based on these data, the opinion of the Subcommittee is that the risk posed by the return of the MUSES-C sample to Earth is infinitesimal*."

The SSB Task Group's review states that (Space Studies Board (National Research Council), 1998{9}), "*For many asteroids, the requirements for life to have emerged (presence of liquid water, organic matter, and a usable energy source) were probably met very early in their history. Although the known meteorites derived from such asteroids reveal no evidence of biological activity, those meteorites cannot be regarded as having sampled the entire population of such* *asteroids. Similarly, although the natural meteorite influx has apparently had no deleterious effect on terrestrial biology, it is not certain that samples of every asteroid type have fallen on Earth. Furthermore, although natural radioactivity present within the asteroidal/meteoritic material would have been adequate to sterilize any dormant organisms possibly present within the lithic fraction of such objects, if pockets of relatively pure water ice were to exist within an asteroid of this type, attenuation of the natural radiation field within that ice could in principle have permitted survival of putative dormant organisms.*

"*Undifferentiated, metamorphosed asteroids as well as most differentiated asteroids are dry and have been heated to very high temperatures. A minor fraction of S-type asteroids may have experienced a transient episode of aqueous activity, but the great majority of S-types have never been exposed to liquid water. Like C-type asteroids, S-types would have experienced sterilizing doses of radiation from decay of natural radionuclides during the 4.5 Gyr since cessation of any aqueous activity. Thus, for S-type asteroids and other non-C/P/D-like asteroid types, the potential for a living entity to be present in returned samples is negligible. However, there is clear evidence in meteorites that substantial cross-contamination of material from one asteroid to another has occurred. It is uncertain whether such material would constitute such a trivial volume of the surface material on asteroids that the odds of sampling it would be negligible.* "

"For samples returned from … undifferentiated metamorphosed asteroids…, the potential for a living entity in a returned sample is extremely low, but the task group could not conclude that it is demonstrably zero. Based on the best available data at the time of its study, the task group concluded that containment is not warranted for samples returned from these bodies. However, this conclusion … should be re-examined at the time of mission planning on a case-by-case basis."

The SSB Task Group review also discusses what scientific investigations could be undertaken to reduce the uncertainty in the assessment of the biological potential of asteroids(Space Studies Board (National Research Council), 1998{13}).

Hazard Identification Summary

Biosecurity Australia considers that the potential for a living entity to be present in a returned sample from a type S undifferentiated metamorphosed asteroid is extremely low to negligible. Biosecurity Australia also endorses, in principle, the opinion of the SSB Task Group that "*the potential for a living entity in a returned sample is extremely low, but the task group could not conclude that it is zero. Based on the best available data at the time of its study, the task group concluded that containment is not warranted for samples returned from these bodies*".

Although this SSB Task Group opinion is based on best available data at the time, the potential for significant hazards to exist cannot be completely dismissed due to the many remaining uncertainties as well as evidence of cross contamination of asteroids. Biosecurity Australia therefore considers it appropriate to proceed onto the next stage of risk assessment.

RISK ASSESSMENT

Release assessment (Potential for the returned sample to be contaminated)

The potential for the returned sample to be contaminated with agents of concern and subsequent adverse environmental or human health effects depends on the likelihood of the entity being present on the target asteroid; collecting the entity in the sample; and the entity being capable of causing significant pathological or ecological effects if inadvertently released on Earth.

The NRC 1997 report, "Mars Sample Return - Issues and Recommendations", recommended that samples returned from Mars be contained and treated as though they were potentially hazardous until proven otherwise (Space Studies Board (National Research Council), 1997{8}). However, the diverse types of small solar system bodies comprise many different environmental conditions. In conducting a case-by-case assessment, the SSB task group considered the various different bodies, the natural influx to Earth, the possible nature of extraterrestrial life, and the range of potential adverse effects that might be caused by incoming sample materials.

If micro-organisms exist at all on small bodies, they are most likely to be anaerobic organisms similar to those found in harsh Earth environments. These include hydrothermal systems, sea ice, oligotrophic aquatic environments and deep basaltic rock. The natural influx of extraterrestrial materials arriving over time has exposed Earth to risks the same as or similar to those potentially posed by samples deliberately returned from these bodies. The very low risk of either an active or dormant organisms being present in the returned sample is further supported by the complete absence of evidence of fossilized extraterrestrial life forms or chemical fossils in meteorites.

The review generally assumes that extraterrestrial life, if it exists, would share a common or similar origin with that on Earth. However, if the extraterrestrial entity evolved independently of terrestrial life, it may not even share a common biochemistry with life on Earth. This will have implications for the sample handling and life detection study protocols.

As discussed previously, the SSB task group concludes that undifferentiated metamorphosed asteroids are dry, have been heated to very high temperatures and sterilizing doses of radiation from decay of natural radionuclides since cessation of any aqueous activity. Therefore, the potential for a living entity to be present in returned samples from S-type asteroids is extremely low. However, because there is clear evidence in meteorites that substantial cross-contamination of material from one asteroid to another has occurred, it cannot be concluded that it is necessarily zero.

Biosecurity Australia endorses this SSB conclusion and considers that the potential for a living entity (active or dormant) to exist in the returned sample is extremely low to negligible. However, it cannot be completely dismissed due to the many remaining uncertainties as well as evidence of cross contamination of asteroids. Our knowledge of the environment of various small solar system bodies and of the ability of terrestrial micro-organisms to survive extreme environments continues to expand. However, at this time, it is not possible to predict definitively the presence of living entities on each small solar system body although the likelihood is considered to be negligible for a sample from an S-type asteroid. The small, but significant possibility of cross-contamination from impact materials originating from other bodies must also be considered. It is therefore necessary to consider the likelihood of environmental exposure.

Exposure assessment

The mission

The return and recovery mission is anticipated for June 2007. The sample returned by the MUSES-C mission is expected to be only a few grams. The asteroid, 1998 SF36, which is classified as a type-S (an undifferentiated, metamorphosed asteroid) is believed to be made of olivine rich silicate. ISAS proposes to use the Woomera Prohibited Area for the recovery of the sample contained in a sealed re-entry capsule, which descends suspended by a parachute.

The sample is contained in a special canister, which is about 6cm long and 3cm in diameter. The canister is pushed and tightly sealed into a container aboard the re-entry capsule. The container is sealed in vacuum condition and sealed by double metal o-rings. The re-entry capsule weighs about 20kg and its diameter is 400mm.

Ten hours before re-entry, the mother spacecraft jettisons the capsule which is given a low spin of several revolutions per minute. The parachute is deployed 10km above the surface. The capsule surface is made of forward and aft heat-shield shells, which are removed when the chute is deployed. Those shells passively fall down to the ground. The chute suspends the sample container as well as the beacon transmitter. The touch down velocity of the capsule is around ten meters per second. The chute is cut off on landing to prevent it from being pulled by the wind. The beacon will transmit the radio signal for about two days if necessary. No hazardous material is left aboard the capsule except the lithium battery. On recovery, the lithium battery is immediately removed at the touch down point. The whole capsule payload is then immediately put into a special larger container filled with nitrogen gas also at the touch down point. The pressure inside is at atmospheric pressure. This container will have also sealing devices and a pressure gauge to monitor for any leaks throughout the transportation.

Re-entry temperatures

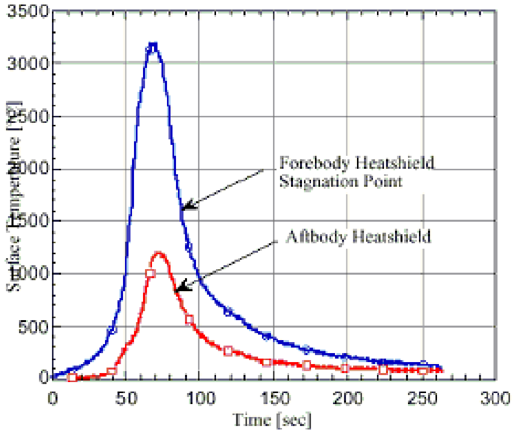
The following information on re-entry temperatures has been provided by ISAS (Institute of Space and Astronautical Science (ISAS), 2001{4}).

ISAS has demonstrated by analysis that all of the mother spacecraft will be burnt-up/ablated during the very high speed re-entry. The heat load depends on the size of the component which is a factor of both an equivalent diameter and the mass-to-size (sphere-equivalent diameter) ratio. Smaller components are exposed to a higher heat load. An analysis of the spacecraft panels indicates that they will be melted down before descending to an altitude of 80 km. During re-entry, the outer panels break out and onboard components are disassembled from the spacecraft and re-enter individually at the velocity of 11.5 km/s. The heat flux on each component is thereafter different dependent on its size and mass and is also based on the ballistic parameter that is the function of the drag coefficient and the ratio of the mass to the sphere-equivalent radius. Approximately, any object whose equivalent diameter is smaller than 1 meter is melted in this re-entry. The High Gain Antenna (HGA) components have larger equivalent diameter, however, the corresponding mass-to-size parameters are very small and they are also melted during the flight.

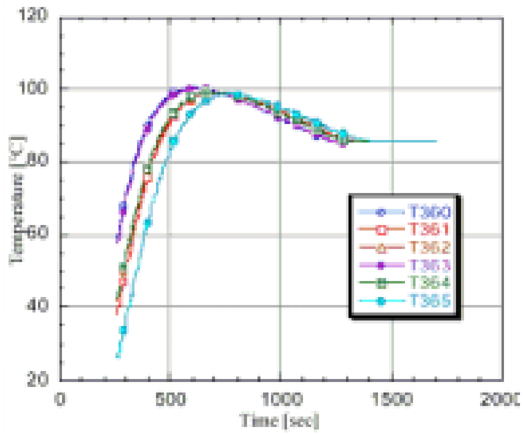
Any carbon fibre reinforced plastic (CFRP) material used in the spacecraft will delaminate into smaller pieces and be destroyed at the early phase of the re-entry. It ablates beyond a certain heat flux and the analysis concluded that it will be melted/ablated completely.

The total heat input integrated in this trajectory amounts to almost ten to twenty times as much as that in the usual re-entry from low Earth orbit. Every part of the spacecraft is predicted to be melted/ablated completely before it hits the ground.

The re-entry capsule from the MUSES-C trajectory experiences 265 MJ/m^2 total heat load. The capsule heat shield shells are heated to high temperatures during the re-entry, including when they are separated from the capsule payload at the chute deployment.



Time history of the Forebody/Aftbody Heatshield. (t=0: reentry to parachute deployment). Chart courtesy of ISAS.



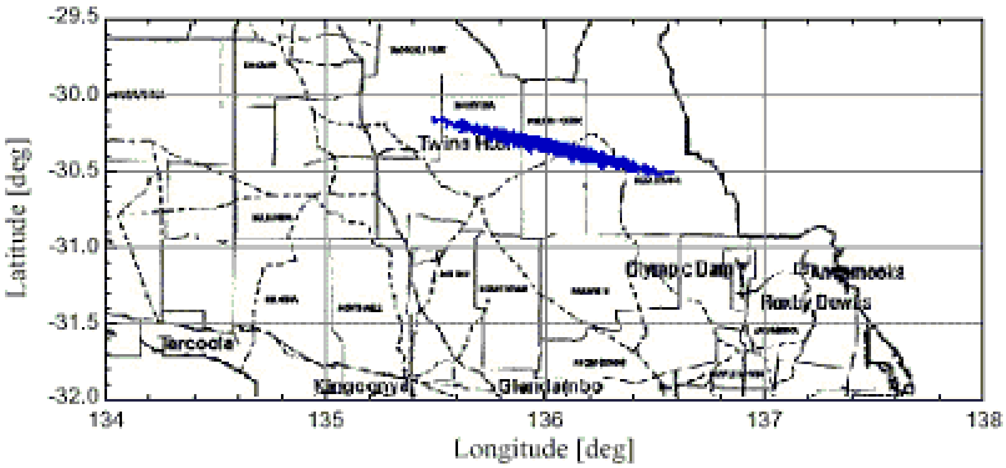
Time history of the Temperatures at the Sampler Container. (t=0: reentry to landing). Chart courtesy of ISAS.

The landing zone

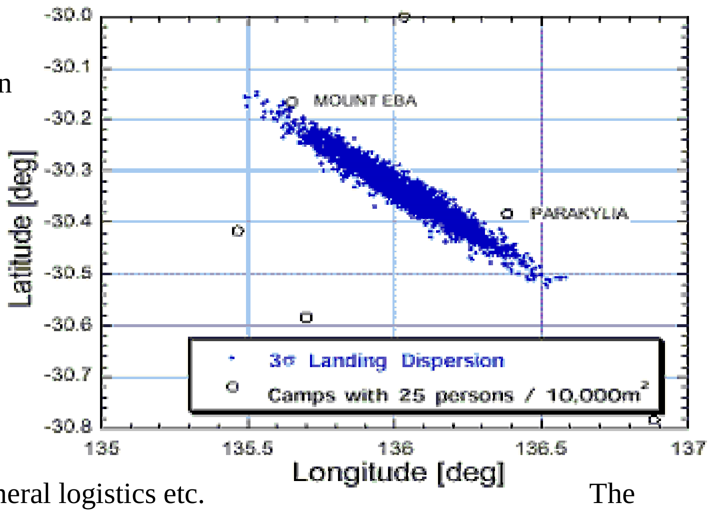
A likely landing dispersion area for recovery within the Woomera Prohibited Area is about 100 km in an east to west direction and about 40 km north to south. The shape is an ellipse with the major axis lying between the two points below:

Latitude:	S 30	degrees:	9	minutes:	0	seconds
Longitude:	E 135	degrees:	29	minutes:	0	seconds
Latitude:	S 30	degrees:	31	minutes:	15	seconds
Longitude:	E 136	degrees:	36	minutes	0	seconds

Maps courtesy of ISAS



As advised by ISAS, the optimum location of the ellipse within the Woomera Prohibited Area has not been finalized. Determination of the best placement will be undertaken in consultation with Defence, especially the Ranges Group at the Defence Support Centre Woomera (DSCW). Such a meeting involving ISAS at Woomera will take into account all key considerations including safety, environment and heritage, terrain conditions, recovery access, instrumentation placement, general logistics etc.



The ellipse location provided is representative/indicative only as there are various options within a latitude and longitude somewhat broader than stated above. Re-entry is expected between the end of May to the beginning of June, 2007. The exact date and time will be determined very accurately three months prior to re-entry.

According to ISAS, the designated area is dry and has a flat gradient, red clay soils with pebbles, no rivers but many small waterholes. The area contains some small, scattered pastoral homesteads. The area also includes the railway and some designated properties. The population density is estimated to very low. As the re-entry time will be predicted precisely, notice of re-entry time (to within twenty minutes) can be provided one week prior to the recovery to avoid any risk of people being hit by the heat shield and the suspended payload.

The landing area is within the Kingoonya District of South Australia and stretches from Mount Eba in the north-west to beyond Parakylia in the south-east. Woomera is approximately 70-80 km north of the southern most point of the proposed landing zone.

The following information on the Kingoonya District was obtained from the South Australian Department of Primary Industries and Resources soil conservation web site (South Australian Dept of Primary Industries and Resources , {7}):

The Kingoonya Soil Conservation District (SCD) is located approximately 600 km north-west of Adelaide in South Australia and is 65,815 km2 in size. The district has a population of about 4000 people, mainly concentrated in the towns of Roxby Downs and Woomera. Roxby Downs has a population of about 2500 and Woomera about 1000. Other population centres are the settlements of Andamooka, Pimba, Glendambo, Kingoonya and Tarcoola. Shopping facilities are concentrated in the eastern side of the district, although most stations obtain their supplies by mail truck or bus from Port Augusta. The population consists in the main of people associated with the mining and defence industries. The pastoral community makes up a small proportion of the population but manages the vast majority of the land.

Salt-lakes form the southern and eastern boundaries of the district. The Dog Fence forms much of the northern boundary and all of the western boundary. The Maralinga Tjarutja Aboriginal Lands lie to the west and north-west of the district.

Topography of the district is flat to undulating, with variations in altitude from just above sea level to about 300 m above sea level. Drainage over the southern and eastern parts of the district is into salt-lakes by way of minor drainage lines. The northern parts drain into Lake Eyre South via larger creek systems. Drainage of much of the central and western parts is into numerous small salt-lakes and claypans.

The climate of the District is hot and dry with a short cool winter. The cooler months are April to October with average maximum daily temperatures ranging from the upper teens in June and July to the mid to upper twenties in April and October. The average minimum temperatures are less than 15° C and fall to around 5° C in July. In the hotter part of the year (late November to March), mean maximum temperatures exceed 30°C over most of the District, and during January and February average near 35°C. The year to year variability of rainfall is very high and average annual totals, which range from less than 150 mm in the north-east to around 200 mm in the south-west, are among the lowest in Australia. No seasonality of rainfall is apparent. On average, once in ten years an annual rainfall total less than 75 mm occurs in the south-west, and 50 mm in the north-east can be expected. Highest daily falls of rain occur in the warmer months when between 100 mm and 200 mm have been recorded in a single day.

Between April and June, winds are generally light with little directional preference. Through July and August, the wind direction is most frequently from the north-west to south-west but a north to north-easterly flow is also common. During the hotter part of the year (October to March), the prevailing surface winds over most of the District are from the south-east to south-west. From December to March, winds in the morning are most frequently from the south-east quadrant, but typically shift to the south/south-west during the day. From September to November, prevailing winds again become easterly. During September and October, strong and gale-force winds are most likely. Wind observations for the Kingoonya District are available from three sites: Tarcoola, Woomera and Coober Pedy.

The proposed re-entry in June should therefore encounter only light winds, cool temperatures and little likelihood of rain.

Land use in the Kingoonya District consists of stock grazing on native pastures, mining, tourism, limited rural living and defence industry operations. Most stations run predominantly sheep for wool production. Two stations run entirely cattle, while several others run at least some cattle. Vegetation is predominantly chenopod low shrub lands and mulga low woodlands.

By far the most extensive land use by area is the production of wool and mutton. Merino sheep are run on 20 of the 22 stations. Two stations run cattle exclusively and several others run smaller numbers of cattle in conjunction with their sheep. Sheep stocking density averages 4-6 sheep per km^2 although it will vary from 2-8/km^2. Where grazed, stocking density for cattle is roughly 0.5/ km^2.

The South Australian Dog Fence which forms all of the western and much of the northern boundary of the district is vital to the ongoing production of wool. Early experience demonstrated that sheep production is not viable without protection from dingos.

A survey of landholders by the Kingoonya Soil Conservation Board identified rabbits as the major environmental concern of pastoralists in the District. The advent of myxomatosis in the 1950s caused a major decline in rabbit populations and it appears to have prevented subsequent large scale plagues. However, its effectiveness has now waned. Rabbits occur throughout the District. The populations vary from $<10/km^2$ in some land systems such as Arcoona and Christie to $>750/km^2$ in land systems in the north-east of the District and adjacent lakes, e.g. Roxby, Emu and Phillipson.

Other feral animals include brumbies (feral horses), goats, camels, foxes and cats. Brumbies occur in the north-east of the District. Camels occur in the sandy country of the west and south-west of the district. They migrate into the District from the Maralinga lands and cause frequent damage to the dog fence. Goats occur in the areas adjacent to the Gawler Ranges, where their numbers fluctuate in response to seasonal conditions. Foxes kill young lambs and native fauna. Cats also destroy native fauna.

The survey of District land managers identified kangaroos as a land management concern. Artificial watering points and the Dog (dingo) Fence have provided conditions that have allowed the kangaroo population to increase. Permanent water and the Dog Fence have reduced the necessity for, and ability of, kangaroos to migrate. The population still moves about the District but is more stable. Kangaroos are now able to use more of the country on a more continuous basis. They increase the grazing pressure, compete for food and water and damage fences. Aerial survey figures indicate a mean red kangaroo density of 5/km² during that time. Western grey kangaroos occur in low numbers after a run of good seasons.

Soil and vegetation degradation issues which may occur in the District include; degradation of rangeland vegetation by stock, rabbits and large populations of kangaroos, scalding of texture contrast soils where vegetation has been removed, wind erosion of light textured soils, gully erosion of clay soils of the gilgai (crab hole) land types, wild fire, drought, mining and mineral exploration, defence operations and off road vehicle use.

The low and highly variable rainfall provides limited opportunities for vegetation re-establishment and makes rehabilitation in short time frames difficult. The native vegetation is resilient and adapted to the environment and will establish where soil and rainfall provides suitable conditions for germination.

The land systems of the Kingoonya Soil Conservation District have been mapped by the Pastoral Management Branch of the Department of Environment and Natural Resources. The following land systems exist within the proposed landing zone:

- sand dunes and stony country (dunes encroaching plains) with woodland and shrubland vegetation
- plains (calcareous plains) with woodland, scrubland and shrubland vegetation
- uplands with shrubland and scrubland vegetation

There is virtually no naturally occurring permanent potable water in the district. There is no potential source of water suitable for irrigation and very high evaporation rates. Domestic, industrial and stock water is derived from local ground water or Great Artesian Basin tapped by bores or wells; local surface water stored in excavated earth tanks or dams; reticulation systems originating outside the district or on properties; ephemeral natural water; and rainwater tanks. The use of dams and earth tanks is constrained by the availability of catchment areas occurring in conjunction with suitable water-holding clay. If useable ground water is available large dams are not sunk but smaller catch-holes may be used to spell permanent waters. Surface waters are widely used in the east where good ground water is scarce and dam sites are relatively plentiful.

Risk scenarios

- If the sample container is not properly sealed into the capsule after sample collection:

  The sample catcher transfer device inside the spacecraft is equipped with two micro switches that detect the translation displacement of the catcher with respect to the container in the capsule. As a back-up for this function, the capsule container temperature is monitored through the telemetry (by measuring the temperature shift and the heat conductivity difference). The location and position of the sample catcher is therefore verified. Latches are activated electronically and confirmation is received on the ground. However, in the event that the container is not properly sealed, the aft heat shield shell will not be properly seated and the capsule will not withstand the high heat flux environment during the re-entry. The capsule including the sample will burn up during the re-entry and the sample will therefore be passively sterilised by the extremely high re-entry temperature. Adequate notice should be provided to the Australian Quarantine and Inspection Service (AQIS) of the success or failure of the sample collection and its sealing.

- If the sample container breaks open on impact:

The capsule descends suspended by parachute. Touch down velocity will be around ten meters per second. As the sample is collected under the vacuum of space, the container should remain negatively pressurised on its return. An absence of negative pressure will indicate that the container has been breached. Although the sample container is sealed by double o-rings together with the spring force capable of withstanding 280G acceleration, it is expected that, if the parachute fails to deploy, the impact to rocks will exceed this acceleration level and the capsule could break up. The capsule descent velocity at sea level without its chute deployed would be approximately 50 m/sec.

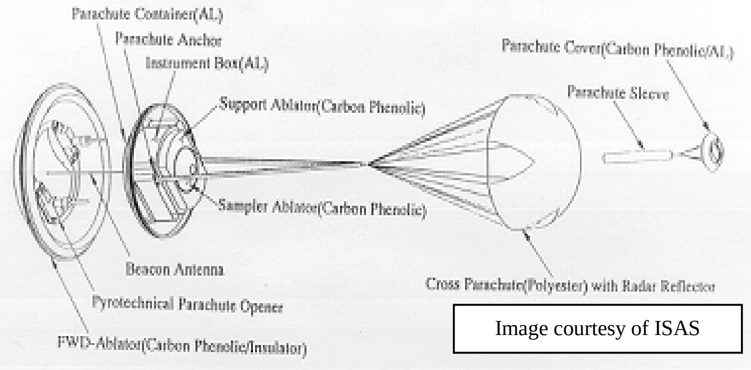


Image courtesy of ISAS

On impact, the largest radius of any rebounding object is likely to be about 190 m. If the wind speed is assumed to be 10 m/sec constantly, the dispersion radius is expanded to about 250 m (Institute of Space and Astronautical Science (ISAS), 2001{4}).

If the sample container breaks open, ISAS has proposed to remove the soil around the capsule landing point that may potentially have been contaminated with the sample and restore the soil to a safe condition. ISAS has stated that, if the sample container breaks open, the surface soil to a depth of one-inch will be collected and burnt in a kiln. ISAS has also stated that the soil area to be removed will be two times as deep as that of the surface crater and a radius twice the distance from point of impact to where the furthest fragment of the capsule is found. The soil will be collected and undergo the high temperature kiln process.

Biosecurity Australia acknowledges these ISAS proposals but notes that the proposed depths for removal may be conflicting and, in some cases, excessive. The exact distance and depth should be determined at the time based on the degree of damage (which will depend on the impact surface density (ie sand, soil, rock) and impact velocity) and wind speed and direction. Alternative strategies such as heat may also be considered.

Machinery and other equipment exposed to potentially contaminated soil should also be treated with a broad spectrum sporicidal disinfectant or other approved treatment. AQIS approval of the disinfectant or alternative treatments will be required well before re-entry.

- If there is contamination on the mother ship, heat shields or outside of the capsule:

The spacecraft is designed so that no fragment or dust particle of the sample should be outside the container. The catcher separator rotates and the sample is stored inside a closed space. The sample guide-tube automatically shuts its aperture, when it is extracted from the sample catcher. The sample guide-tube, which remains part of the mother spacecraft, is made of polymer and aluminium. It will have some asteroid surface material adhering to it. For the return capsule, no sample dust is nominally outside the container. However, ISAS admits that there is the slightest possibility that some dusts may stick to the surface of the aft heat shield shell outside the container.

With the exception of a very small surface area between the sample container and the aft body ablator, the outside of the sample container cannot physically become contaminated. This amount of sample material on this small area is likely to be very small if present at all. The area is also well protected at impact.

The mother spacecraft re-enters into atmosphere above the Woomera area and burns up completely during re-entry. No radioactive material is aboard. The sample guide-tube, as part of the mother spacecraft, will suffer the same fate.

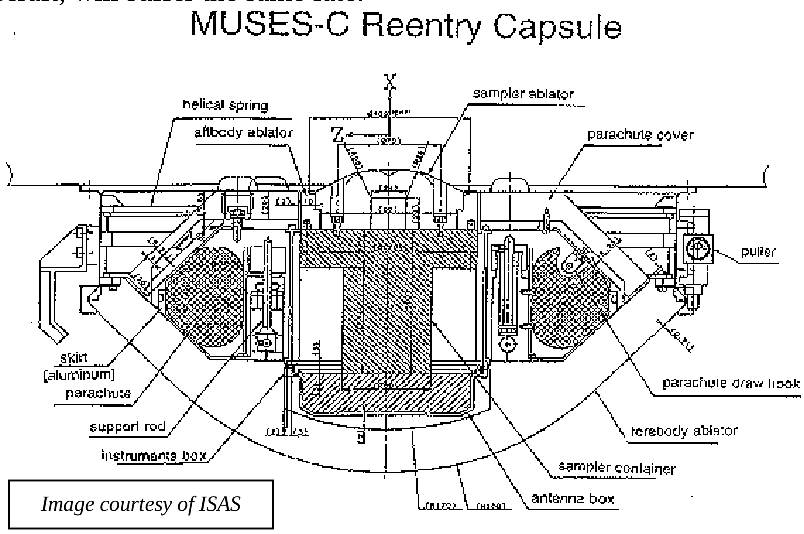


Image courtesy of ISAS

The heat shield shells jettisoned are made of CFRP and not hazardous. Although they are not equipped with active beacon transmitters, ISAS will search and remove them. Coloured ribbons will be attached to assist in locating them. The outside of the heat shields will have been heated to approximately 1000 to 3000^{0}C during re-entry.

As a precautionary measure, Biosecurity Australia recommends that the capsule and all associated materials be placed into a secure, sealed container, as soon as possible after recovery.

- If the radio beacon (transmitter) fails to operate

The optical trace of the loci enables the touch down point to be estimated. The capsule's beacon transmitter works for about two days and can be localized via hand-carried receiver. Optical loci tracking will be combined with the radio direction finding strategy. If the transmitter fails to function, the optical loci tracking will be the primary means for estimating the touch down point. Additional options are being explored such as the use of radar and monitoring the infrared signature of re-entry by surveillance satellite.

- If new information becomes available prior to re-entry in 2007 providing evidence of unacceptable risk:

It is technically feasible to conduct a divert manoeuvre so that the mother spacecraft, including capsule, avoids re-entry. This would only be considered necessary by Biosecurity Australia if new information indicating an unacceptable risk was to become available prior to re-entry in 2007. ISAS would be required to inform AQIS of any such new information.

Exposure assessment summary

Due to the small, but significant possibility of cross-contamination from impact materials originating from other bodies and the many remaining uncertainties concerning the potential for viable entities to exist, it was necessary to consider the likelihood of environmental exposure. The proposed landing zone is isolated, arid with relatively sparse, yet resilient vegetation and low densities of wildlife and livestock. In the highly unlikely event that the sample contained a pathogenic or environmentally dangerous organism and the container ruptures on impact, appropriate measures are available to control any adverse effects.

Consequence assessment

Samples returned from small solar system bodies could be considered bio-hazardous if they contain living entities pathogenic for Earth organisms or capable of causing adverse ecological effects either by displacement of native life forms or by indirect or direct modification of ecosystems as a result of the activities or presence of organisms from outside the system.

It was previously concluded that the potential for a living entity to be present in returned samples from undifferentiated metamorphosed (type S) asteroids is extremely low to negligible but not necessarily zero. In the absence of information on the effects of introduced micro-organisms on established microbial communities, the SSB task group considered "*the probability that an extraterrestrial anaerobic micro-organism could contaminate a suitable environment on Earth to be very low, but not zero*."

Biosecurity Australia supports this opinion in principle; however, it must be acknowledged that much more information is necessary to accurately determine the risks associated with return samples from small solar system bodies. Although this will continue to expand over time, much of the necessary information required will be obtained in the future by sample return missions. Until additional information is available, it is prudent to consider risk management procedures for return samples from small solar system bodies.

RISK MANAGEMENT

The SSB task group's conclusions and recommendations on containment and handling of samples returned from small solar system bodies are based on its analysis of the potential for a living entity to exist in such samples. Their recommendations were provided as a guide only and not as an inflexible protocol with the final decision to be based on the best judgment of the decision makers at the time and, when possible, on experience with samples previously returned from target bodies.

For samples from undifferentiated metamorphosed asteroids, the SSB task group recommends that no special containment and handling is warranted beyond what is needed for scientific purposes. However, the task group qualifies this statement by stating that confidence in this "*recommended approach is still high but for which there is insufficient information at present to express it absolutely. This lesser degree of confidence does not mean that containment is warranted for those bodies; rather, it means that continued scrutiny of the issue is warranted for the listed bodies as new data become available.*"

Biosecurity Australia considers the potential for a living entity to be present in and subsequent adverse biological effects from returned extraterrestrial samples, derived from type-S undifferentiated metamorphosed asteroids, is extremely low to negligible. However, it must be noted that, to date, there has never very been a sample returns from a solar system body other than the moon. The NASA Stardust mission is scheduled to return sample material from a comet a few months before MUSES-C re-entry. Until laboratory analysis of the returned sample can be undertaken and the absence of any living entity demonstrated, it is considered prudent to ensure the sample is appropriately and securely contained pending such an analysis. Biosecurity Australia, therefore, recommends that, on re-entry, the returned sample and all associated equipment potentially contaminated with the sample be immediately placed into secure impervious containers, transported in a safe manner and exported from Australia to the ISAS laboratories.

In the event of a breach of the sample container, the soil around the capsule landing point should be collected and kiln sterilised. This is consistent with the ISAS proposal. The exact distance should be determined by an AQIS representative and will depend on the impact surface density (ie sand, soil, rock), impact velocity and wind speed and direction. As a guide, however, soil should be removed from an area with a radius twice as long as that from the point of impact to the point where the furthest fragment of capsule is found. All potentially contaminated machinery and associated equipment should be treated with an approved broad spectrum sporicidal disinfectant.

At least 6 months prior to re-entry, ISAS should provide AQIS with detailed documentation of all relevant aspects of the recovery. This includes operational procedures for the location, recovery, containment and transportation of the capsule and contingency plans including soil collection, transportation, proposed disinfectant and/or other treatments of potentially contaminated soil and equipment, etc.

Once the container leaves Australia, it is outside the jurisdiction of quarantine authorities. However, Biosecurity Australia recommends that ISAS maintains secure containment and handling procedures during transport and in the laboratory until appropriate analyses demonstrate beyond reasonable doubt the safety of the sample. Biosecurity Australia also supports the recommendations of the SSB task group (Space Studies Board (National Research Council), 1998{13}) concerning the testing of returned samples as being appropriate for the detection of a diverse range of possible microbial entities. It is highly probable that the test results of the

MUSES-C sample will provide additional confidence to enable controls to be reduced for future sample return missions from other S-type asteroids.

CONCLUSIONS AND RECOMMENDATIONS

Biosecurity Australia endorses, in principle, the findings of the SSB Task Group and the opinion of the Australian Academy of Science Subcommittee on the draft quarantine review of the MUSES-C project, and considers that the overall risk of adverse effects due to the possibility of a viable entity being present on an S-type undifferentiated metamorphosed asteroid and returning in the sample is extremely low to negligible. However, until laboratory analysis of the returned sample can be undertaken and the absence of any living entity demonstrated, Biosecurity Australia considers it prudent to ensure the sample is appropriately and securely contained pending such an analysis. Biosecurity Australia. Therefore, recommends that, on re-entry, the returned sample and all associated equipment potentially contaminated with the sample be immediately placed into secure impervious containers, transported in a safe manner and exported from Australia to the ISAS laboratories. This is consistent with the ISAS proposal. International collaborative research has been proposed by ISAS for the sample. Once safety has been established by ISAS, reimportation for research purposes in non-secure facilities would be acceptable.

In the event of a breach of the sample container, ISAS should remove the soil around the capsule landing point that may potentially have been contaminated with the sample and return the soil to a safe condition. The exact distance will be determined at the time based on the degree of damage (which will depend on the impact surface density (ie sand, soil, rock) and impact velocity) and wind speed and direction. Machinery and other equipment exposed to potentially contaminated soil should also be treated with an approved broad spectrum sporicidal disinfectant. All soil should be removed in sealed containers for subsequent kiln sterilisation. Alternative strategies such as heat may also be considered prior to re-entry in 2007.

At least 6 months prior to re-entry, AQIS should be provided by ISAS with detailed documentation for approval, covering all aspects of the sample collection and removal including appropriate contingency measures.

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