“Protecting the Bodies”

An introduction to planetary protection

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CONTENTS

SOME CORNERSTONES

SPUTNIK November 3rd 1957

GAGARINE April 12th , 1961

GLENN February 2nd 1962

ARMSTRONG, ALDRIN & COLLINS
July 19th 1969

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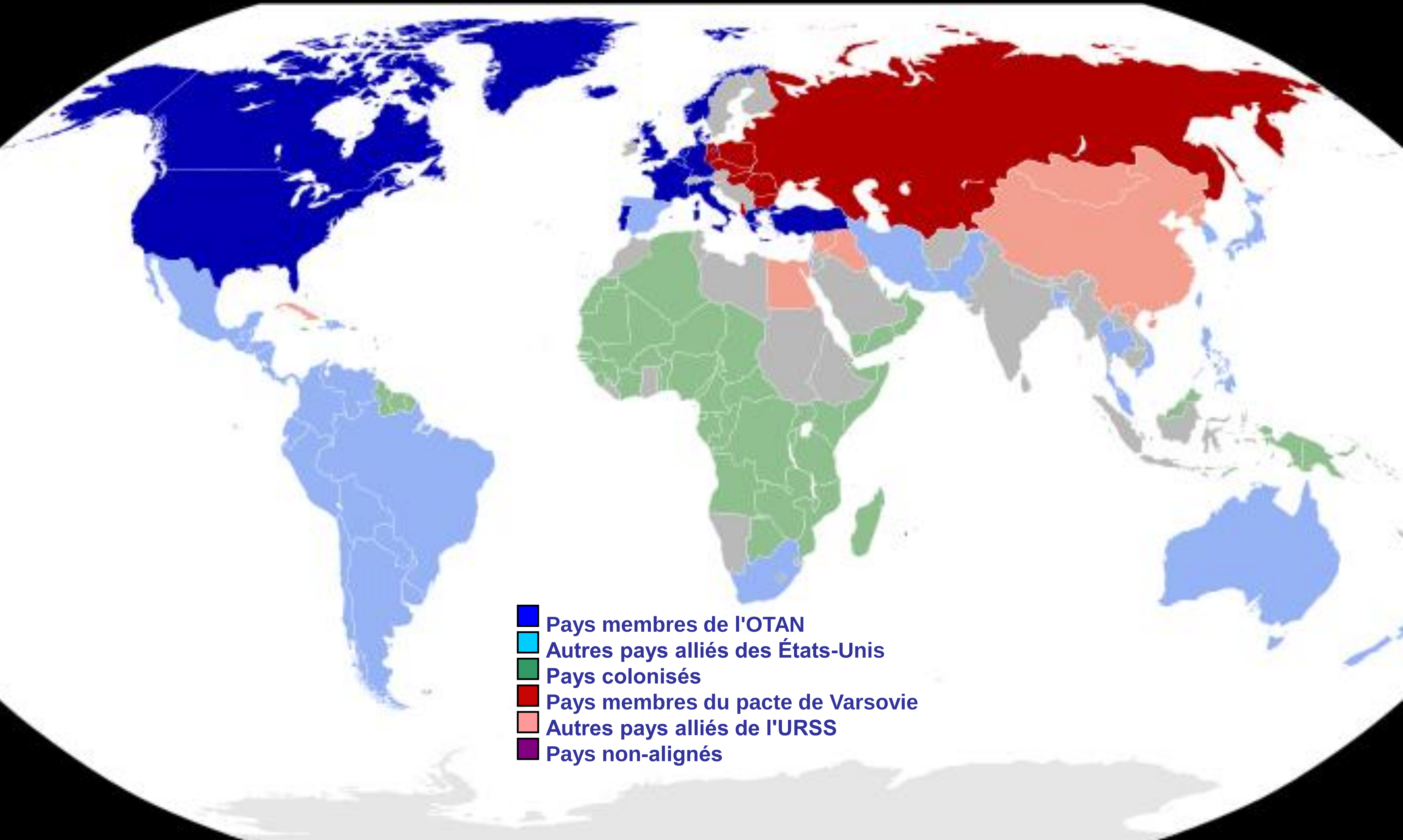
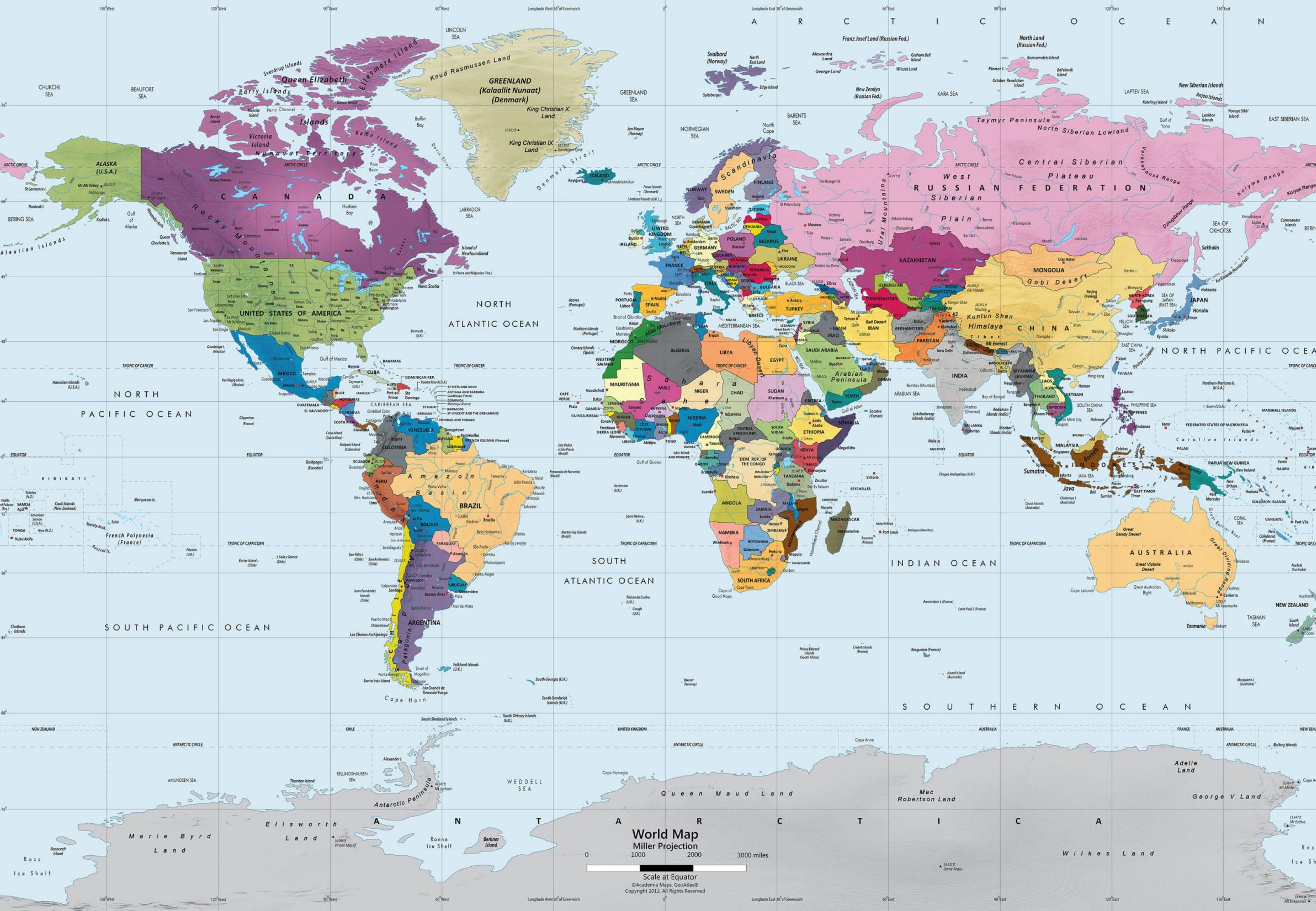

Pays membres de l'OTAN
Autres pays alliés des États-Unis
Pays colonisés
Pays membres du pacte de Varsovie
Autres pays alliés de l'URSS
Pays non-alignés



World Map
Miller Projection
0
1000
2000
3000 miles
Scale at Equator
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ARCTIC OCEAN
NORTH ATLANTIC OCEAN
SOUTH ATLANTIC OCEAN
NORTH PACIFIC OCEAN
SOUTH PACIFIC OCEAN
INDIAN OCEAN
SOUTHERN OCEAN
ANTARCTICA
Queen Maud Land
Mac Robertson Land
George V Land
Wilkes Land
Ellsworth Land
Marie Byrd Land
Ross Ice Shelf
Antarctic Peninsula
WEDDELL SEA
GREENLAND (Kalaallit Nunaat) (Denmark)
Knud Rasmussen Land
King Christian X Land
King Christian IX Land
Queen Elizabeth Islands
Ellesmere Island
Parry Islands
Victoria Island
Baffin Island
Nunavut Territory
ALASKA (U.S.A.)
CANADA
Rocky Mountains
UNITED STATES OF AMERICA
MEXICO
CUBA
CARIBBEAN SEA
Gulf of Mexico
VENEZUELA
COLOMBIA
PERU
BRAZIL
BOLIVIA
PARAGUAY
URUGUAY
ARGENTINA
CHILE
Amazon Basin
Patagonia
Cape Horn
ICELAND
NORWAY
SWEDEN
FINLAND
Scandinavia
UNITED KINGDOM
IRELAND
FRANCE
SPAIN
PORTUGAL
GERMANY
POLAND
BELARUS
UKRAINE
ITALY
ROMANIA
TURKEY
MEDITERRANEAN SEA
RUSSIAN FEDERATION
West Siberian Plain
Central Siberian Plateau
North Siberian Lowland
Taymyr Peninsula
Ural Mountains
KAZAKHSTAN
MONGOLIA
Gobi Desert
CHINA
Himalaya
Kunlun Shan
Tibet
INDIA
PAKISTAN
AFGHANISTAN
IRAN
IRAQ
SAUDI ARABIA
Arabian Peninsula
YEMEN
OMAN
JAPAN
NORTH KOREA
SOUTH KOREA
THAILAND
VIETNAM
MALAYSIA
INDONESIA
PHILIPPINES
PAPUA NEW GUINEA
AUSTRALIA
Great Sandy Desert
Great Victoria Desert
Great Dividing Range
Tasmania
NEW ZEALAND
TASMAN SEA
ALGERIA
LIBYA
EGYPT
Sahara
Sahel
Libyan Desert
MOROCCO
WESTERN SAHARA
MAURITANIA
MALI
NIGER
CHAD
SUDAN
ETHIOPIA
SOMALIA
NIGERIA
DEM. REP. OF THE CONGO
KENYA
TANZANIA
ANGOLA
ZAMBIA
NAMIBIA
BOTSWANA
SOUTH AFRICA
MADAGASCAR
TROPIC OF CANCER
TROPIC OF CAPRICORN
EQUATOR
ARCTIC CIRCLE
ANTARCTIC CIRCLE

LEGAL ISSUES

THE OUTER SPACE TREATY -1967-

- Treaty on principle governing the activities of states in the exploration and use of outer space, including the moon and other celestial bodies
    - Date opening for signature: January 27th, 1967
    - Date of entry into force: October 10th 1967
    - State parties : Ratifications 103 + Signatures 25 (01/01/2015)

THE OUTER SPACE TREATY -1967-

- Article IX of the « Outer Space Treaty » ref 610 UNTS 205:

  «State parties shall pursue studies of the outer space, including the Moon and other celestial bodies and conduct exploration of them so as to avoid the harmful contamination of extraterrestrial bodies and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and when necessary, adopt appropriate measures for this purpose»
- → signed and ratified by practically all Nations involved in space activities since 1967 (including China, France, India, Japan, Russia, USA … ESA member states and associated states but Malta and Latvia)

THE "MOON AGREEMENT" - 1979

- Agreement concerning the activities of States on the Moon and other celestial bodies
  - ref 1363 UNTS 3
  - DOS: December 18th 1979
  - DEF : July 11th , 1984
  - State parties : Ratification 16; Signatures 4 (01/01/2015)

THE "MOON AGREEMENT" - 1979

- Article 7 of the « Moon Treaty »
- «…State parties shall take measures to prevent the disruption of the existing balance of its environment, whether by introducing adverse change in that environment, by its harmful contamination through the introduction of extra-environmental matter or otherwise. State parties shall also take measures to avoid harmfully affecting of the environment of the Earth through the introduction of extra-environmental matter or otherwise ».
- → signed but not ratified by France, neither signed nor ratified by USA, ESA members status variable)

COMMENTS ON THE UN TREATIES

- The Outer Space Treaty is recognized as the solid base for the activities in the outer space. State parties include all space faring nations
- It applies with a legal force to the State parties and is recognised as establishing a customary international law
- The Article IX is opening the door of a large discussion about “harmful contamination” which is considered here as biological and leads to a side effect that the celestial bodies are better protected than the Earth (adverse changes).

COSPAR
PLANETARY PROTECTION
POLICY

COSPAR

- Committee for Space Research
- Science Union in relation with the UN
- Widely open to all the countries which are represented by their science academies
- Open discussions but with a real presence of the most active countries in space utilization and exploration.

THE COSPAR PP POLICY

COSPAR Planetery Protection Policy

(published in *Space Research Today*, COSPAR's information bulletin, Number 193, August 2015)

Last update of terms of reference 13 March 2013.

Note that:

- Statement of a scientific board
- It is not a binding law but might be considered as a soft law
- PPP is referenced in agencie Manageent Instructions and/or national laws
- Five categories of mission have been defined

THE COSPAR PP POLICY

Cat.	Type of Mission	Target Bodies	Recommendations
1	All	Sun, Mercury, Venus, Metamorphosed Asteroids	• Impact probability • Contamination passive control
2	All	Venus, Saturn, Uranus, Neptune, Comets, Jupiter, Chondritic Asteroids, some moon of the external planets, Pluto, Charon, Kuiper-Belt objects...	• Crash probability minimization • Passive control of the contamination
3	Flyby and orbiters	Mars, Europa...	■Minimization of crash probability ■Active control of the contamination
4 A	Contact probes ground or atmosphere	Mars, Europa … No Astrobiology in the payload	•Minimization of probability of off-nominal entry or landing • Active control of the contamination
4 B		Astrobiology in the payload (Mars)	• Same + Stringent active control of the contamination
4 C		Penetrating a special region (Mars)	• Same plus more stringent active control of the contamination
5 No R	Earth return	All	• No restriction
5 R		Mars, Europa, TBD	• Earth crash avoidance • Contact chain breaking • Sample quarantine

CATEGORY REQUIREMENTS FOR SMALL SOLAR SYSTEM BODIES

- Category I, II, III, or IV.

The small bodies of the solar system (…) represent a very large class of objects. Imposing forward contamination controls on these missions is not warranted except on a case-by-case basis, so most such missions should reflect Categories I or II. Further elaboration of this requirement is anticipated.

SAMPLE RETURN MISSIONS FROM SMALL SOLAR SYSTEM BODIES

Category V. Determination as to whether a mission is classified “Restricted Earth return” or not was proposed by a SSB study, Specifically, such a determination shall address the following six questions for each body intended to be sampled:

SAMPLE RETURN MISSIONS

- Does the preponderance of scientific evidence

1. indicate that there was never liquid water in or on the target body?
2. indicate that metabolically useful energy sources were never present?
3. 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. indicate that subsequent to the disappearance of liquid water, the target body has been subjected to extreme temperatures (i.e., >160 C)?
5. that there is or was sufficient radiation for biological sterilization of terrestrial life forms?
6. 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?

SAMPLE RETURN MISSIONS

- For containment procedures to be necessary (“Restricted Earth return”), an answer of "no" or “uncertain” needs to be returned to all six questions.

CATEGORY V : RESTRICTED EARTH RETURN

- The outbound leg of the mission shall meet the contamination control requirements given above.

- Unless the sample to be returned is subjected to an accepted and approved sterilization process, the sample container must be sealed after sample acquisition, and a redundant, fail-safe containment with a method for verification of its operation before Earth-return shall be required. For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility

CATEGORY V : RESTRICTED EARTH RETURN

- The mission and the spacecraft design must provide a method to “break the chain of contact” with the celestial body.
- Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving celestial body for return to Earth; and 3) prior to commitment to Earth re-entry.
- For unsterilized samples returned to Earth, a program of life detection and biohazard testing, or a proven sterilization process, shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample (SSB 1998).

AN EXAMPLE: PHOBOS SAMPLE RETURN

Phobos is the largest moon of Mars

Data from Wikipedia

Name and pronunciation			Diameter (km)	Mass (kg)	Semi-major axis (km)	Orbital period (h)	Average moonrise period (h, d)
Mars I	Phobos	/ˈfoʊbəs/ *FOE-bəs*	22.2 km (13.8 mi) (27×21.6× 18.8) km	10.8×10^{15}	9,377 km (5,827 mi)	7.66	11.12 h (0.463 d)
Mars II	Deimos	/ˈdaɪməs/ *DYE-məs*	12.6 km (7.8 mi) (10×12×16) km	2×10^{15}	23,460 km (14,580 mi)	30.35	131 h (5.44 d)

AN EXAMPLE: PHOBOS SAMPLE RETURN

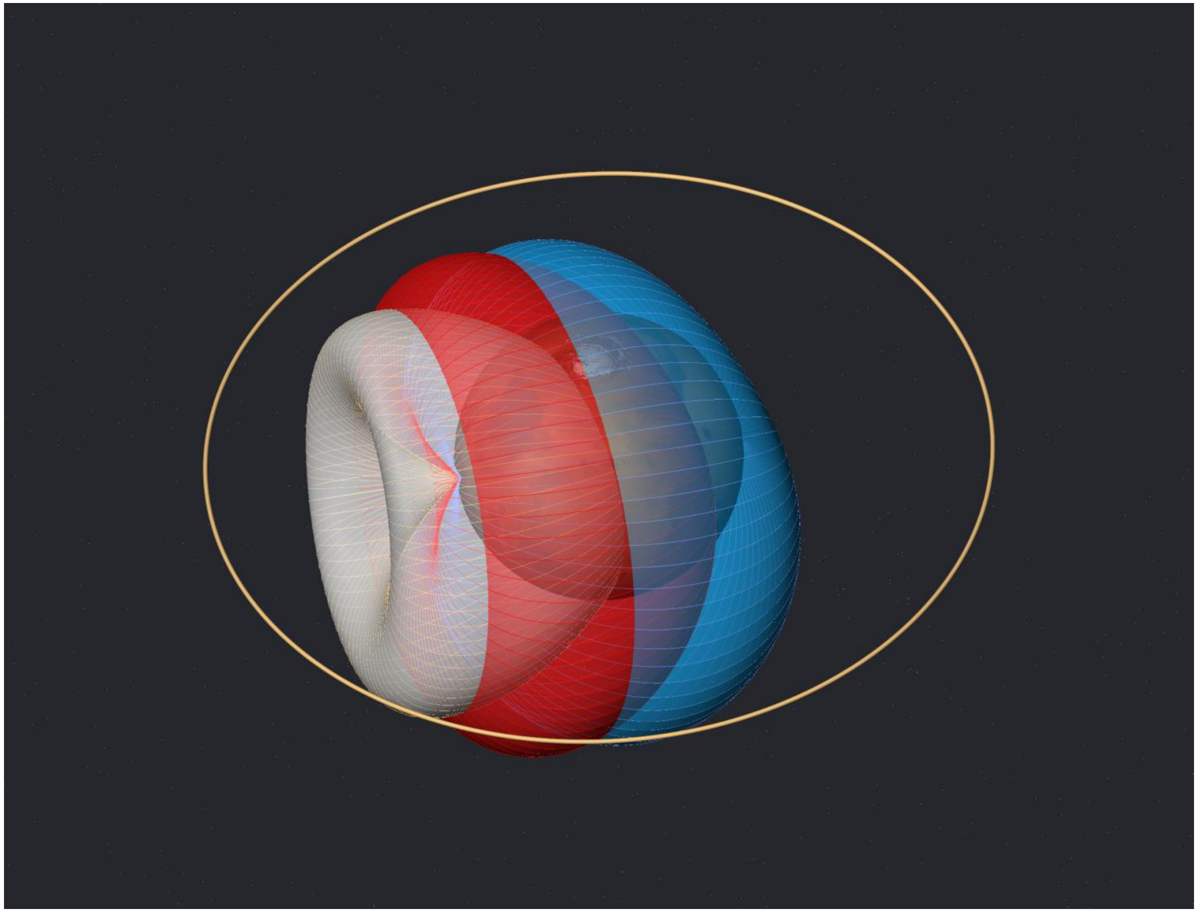

Figure IV.3.2 Orbital paths for ejecta particles launched from Zunil crater at *eje V* =3.8 km/s with β=30 (white), 45 (red), and 60 (blue) degree

Material Transfer from the Surface of Mars to Phobos and Deimos, H. Jay Melosh Kathleen C. Howell, Loïc Chappaz and Mar Vaquero; 2011; NASA report

AN EXAMPLE: PHOBOS SAMPLE RETURN

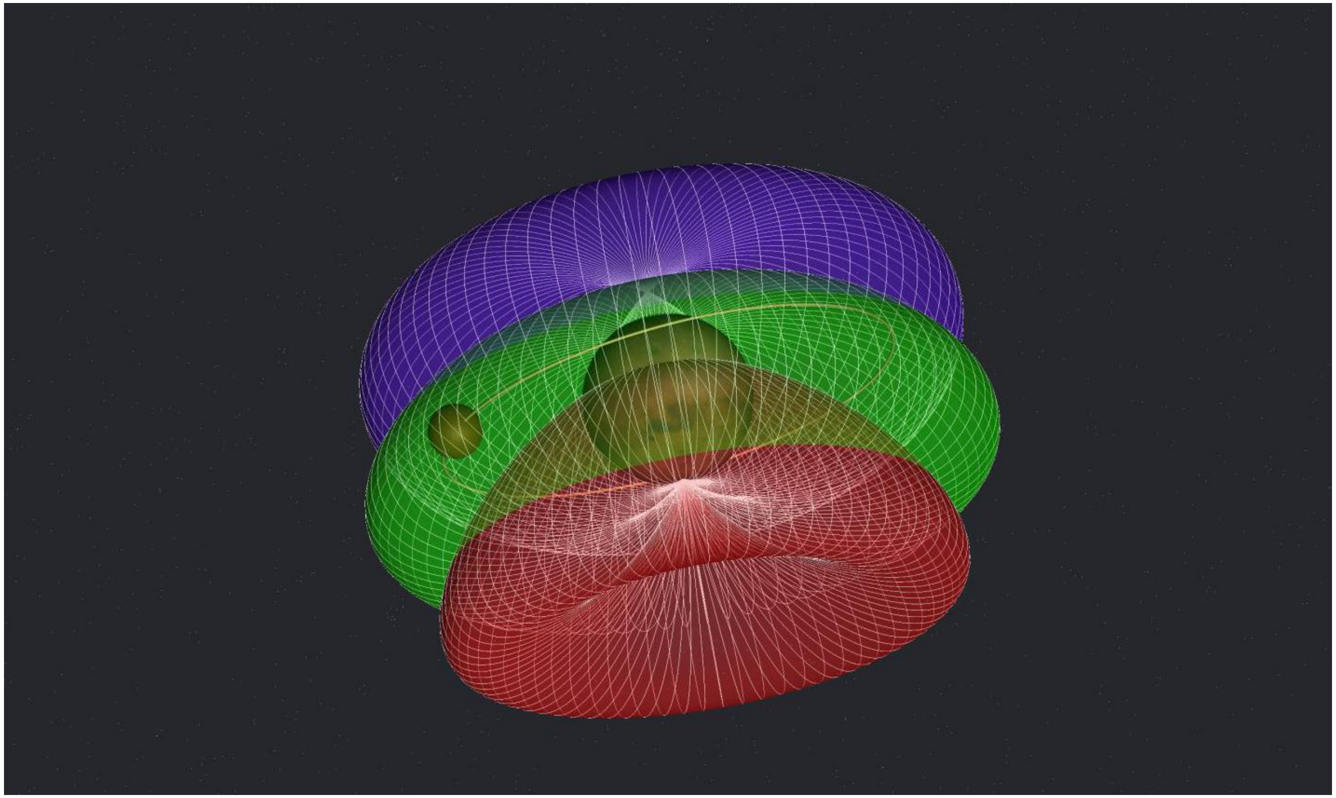

Figure IV.3.4 Orbital paths for ejecta particles launched from McMurdo crater at *eje V* = 4.4 km/s with β=30 (red), 45 (green), and 60 (purple) degree

Material Transfer from the Surface of Mars to Phobos and Deimos, H. Jay Melosh Kathleen C. Howell, Loïc Chappaz and Mar Vaquero; 2011; NASA report

IMPLEMENTATION IN THE SPACE AGENCIES

IMPLEMENTATION OF THE PPP – USA-

- NASA policy directive on biological contamination control for outbound and inbound planetary spacecraft
  - Source : NASA Policy Directive 8020.7G and Space Act 1958
  - Referring explicitly to “The Outer Space Treaty” and to COSPAR guidelines
  - Establishing the function of the Planetary Protection Officer reporting to the NASA administrator.

IMPLEMENTATION OF THE PPP – ESA

- Planetary Protection Working group
  - Gathering scientists and experts and advising the HME directorate
- Planetary Protection Officer
  - One DTEC at ESA
  - One in the SS directorate

In charge of insuring the compliance of the ESA missions with the COSPAR guidelines

DISCUSSION

- The Outer Space Treaty is binding the state parties
- These state parties are responsible of the activities done in and from their territory
- If the activity is conducted by a private entity, the state of nationality of this entity will be responsible
- COSPAR emits only recommendation but they could be considered as a soft law
- The baseline for Planetary Protection is “responsibility and wide consensus”

THE GOLD STANDARD

"VIKING": THE GOLD STANDARD

- Spacecrafts designed in the seventies to land on Mars and to investigate extant Martian life: Category IVb
- Need to minimize the probability of contamination of the surface and to have false positive results
- Policy set up by NASA according with COSPAR recommendation included :
  - Clean room assembly (Class 100 000)
  - Bioburden reduction by dry heat sterilization of the entire Spacecraft

"VIKING": THE GOLD STANDARD

- Pre-sterilization : 300 spore/m² and 5 x10^5 spore total spacecraft load
- Post-sterilisation : 30 spores on the entire spacecraft
- This was obtained by :
  - Cleaning all the instrument and surfaces (Isopropylic alcohol - IPA),
  - Placing the landers in a sealed tight bioshield
  - "Cooking" the Viking landers at 111,7 C for 30 hours

PPP VIEWED BY THE ENGINEERS

A VIEW FROM THE ENGINEERS

- Further missions have not been “cooked” after integration (Mars 96, Beagle2, Mars pathfinder, MERs, *MSL, Phobos Grunt…)*
- Bioburden levels have been obtained by
  - Component sterilisation (heat, chemical, radiation)
  - Sterile assembly in Clean rooms (class 100 000, 1000, 100 or better)
  - Surface cleaning using wipes and IPA
  - Packing in a bioshield

A VIEW FROM THE ENGINEERS

- Planetary protection requirements could lead a mission to be Categories IV and V and requiring a Bioload reduction
- This impacts the choice of the components and the Assembly, Integration and Tests (AIT) procedures
- This impacts the design and the cost of the mission

SO

PP requires careful consideration very early in such projects and it’s a big burden

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A VIEW FROM THE SCIENTISTS

A VIEW FROM THE SCIENTISTS

- Search for life is the main driver for astrobiology
- Biological contamination could impair scientific results of the considered mission or even of further missions
- The sensibility of the instruments is dramatically increasing every year
- Before returning a sample it will be almost impossible to distinguish terrestrial contamination from the discovery of a possible extant Martian (Europan) life. This implies a strict decontamination of the spacecraft and of the instruments.
- Discussion are ongoing about the possibility for some terrestrial organisms to multiply on Mars or to find an reach an ecological niche in the possible ocean of Europa

BUT

Current policies designed to safeguard Mars against biological contamination from Earth are hampering exploration of the Red Planet and should be relaxed, some scientists say.

These "planetary protection" requirements impose heavy financial burdens on Mars missions, partially explaining why no robots have searched for life on the Red Planet's surface since NASA's twin Viking landers ceased operations three decades ago, researchers Alberto Fairen of Cornell University and Dirk Schulze-Makuch of Washington State University write in a commentary published online today (June 27) in the journal Nature Geoscience.

A VIEW FROM THE MANAGEMENT

A TENTATIVE VIEW FROM THE MANAGEMENT

- Planetary protection consideration is mandatory for state parties of the Outer Space Treaty
- PP Policy implementation is the responsibility of the space agencies
- Certification and launch authorization is the responsibility of the governments
- Problems could arise along the course of international missions
- Planetary protection requirements are more and more stringent as missions are more and more ambitious and complex and seldom.

= Costs increase

EVOLUTION AND CONCLUSIONS

WHAT ABOUT THE ICY MOONS.

- Icy moons deserve specific consideration
- Europa is probably the best template for further work on icy moons (Europa/Jupiter System Mission)
- Range of parameters of the environment to which terrestrial micro-organisms are found adapted is widening continuously
- Knowledge about Icy moons is improving rapidly and PPP must be re-considered accordingly

WHAT ABOUT MARS

- Mars is subjected to extensive exploration
- There is a long discussion about the definition of the special region (able to support a Terrestrial extremophile life) based on Water activity and maximal temperature.
- Even there are many Martian meteorites, there is a consensus to consider a restricted Earth return for the future samples

FINAL CONSIDERATION

- COSPAR is maintaining a planetary protection policy since almost 40 years.
- General categorization can be assessed from the scientific goals, the experiments and the target body
- PP requirements must be considered as soon as possible in the development of a project
- Specific measures have to be implemented according with the available knowledge
- Each mission would be evaluated by an appropriate advisory body under the responsibility of the leading agency and/or party

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TO CONCLUDE

- Pristine celestial bodies are a Mankind asset and planetary protection is the way to conduct sounding research and exploration in the future
- Early cooperation on planetary protection issues will build up a wide consensus protecting this asset for the future generations.

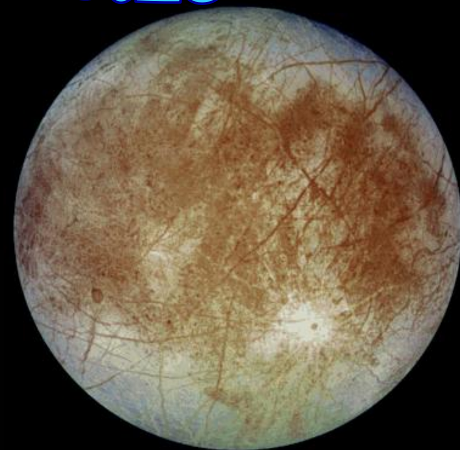
One of my favourite cartoon borrowed from John Rummel, chairman of the COSPAR planetary protection panel and former NASA Planetary protection officer.

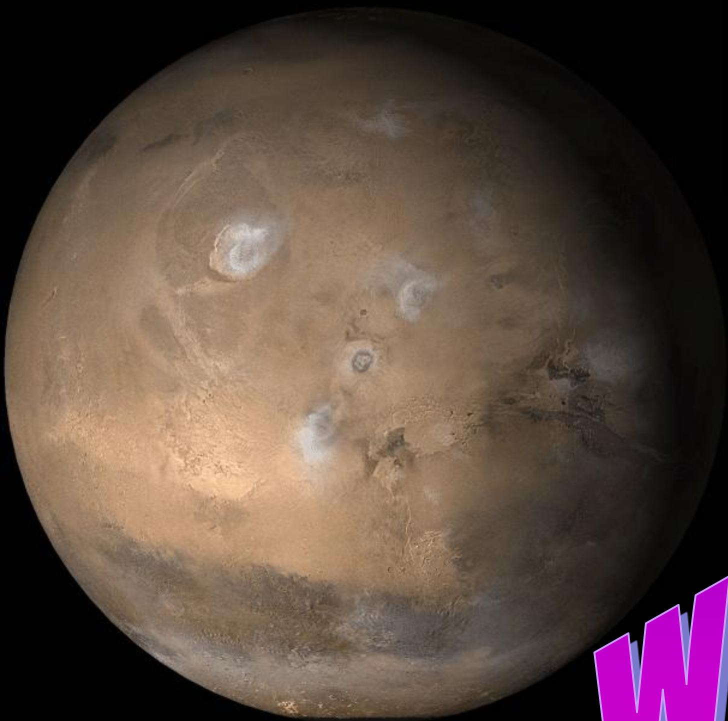
The Basic Rationale for Planetary Protection Precautions

(as written by Bart Simpson, 17 Dec. 2000)

Science class should not end in tragedy....
Science class should not end in tragedy....
Science class should not end in tragedy....
Science class should not end in tragedy....
Science class should not end in

Targetted Celestial Bodies





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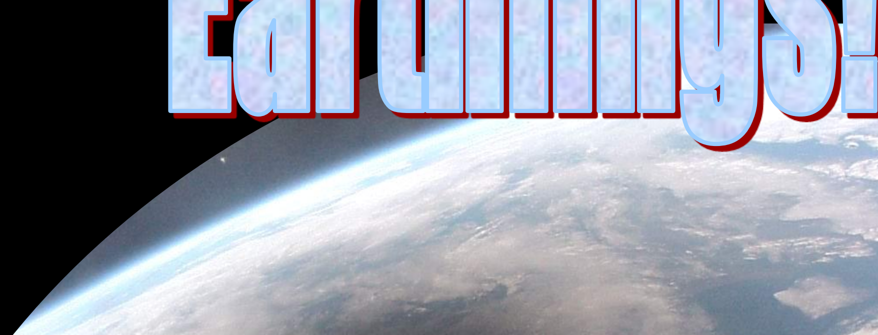
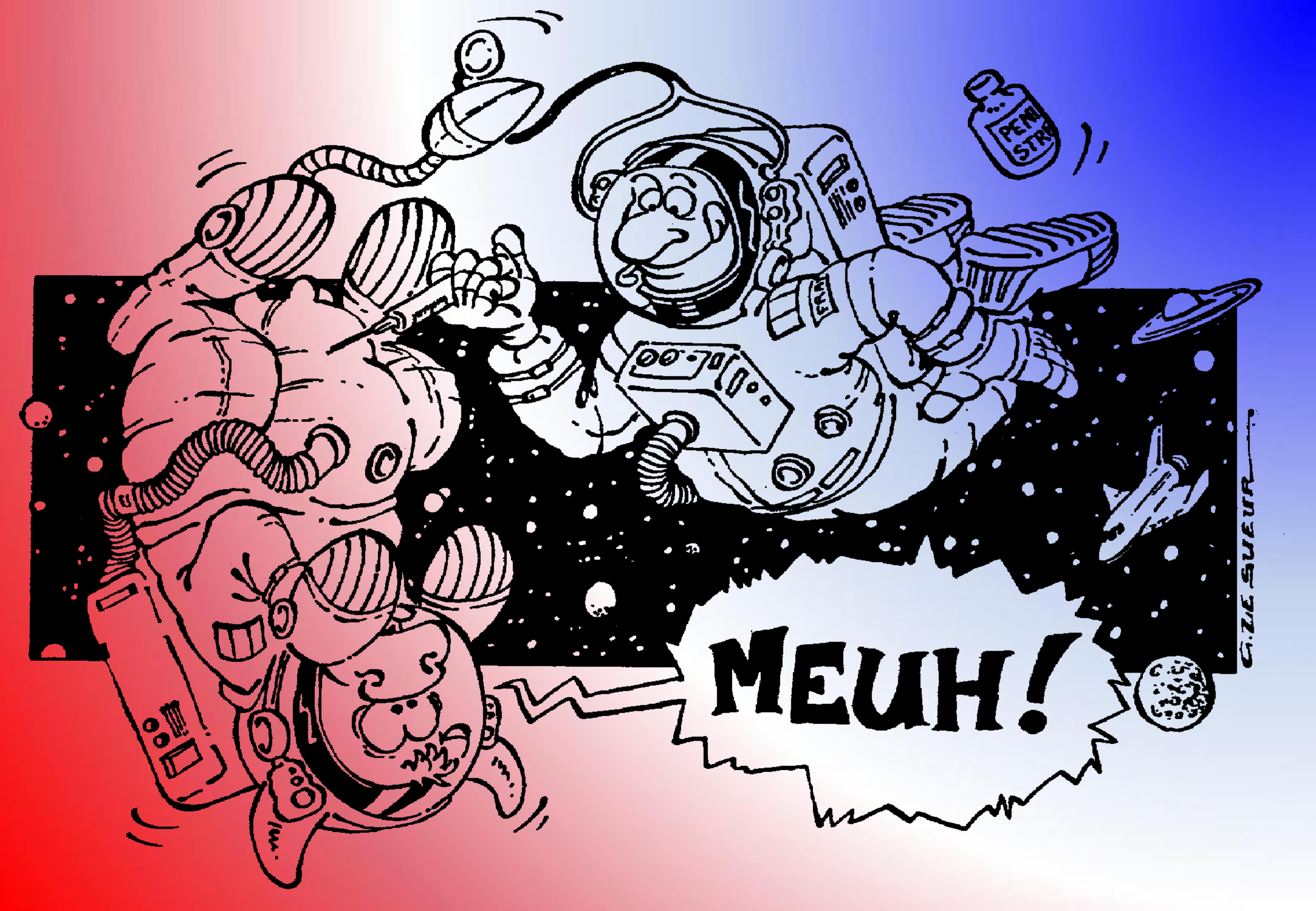
Earthlings!




PENI
STR
FRA
MEUH!
G.LE SUEUR