Committee on Planetary Protection

Modeling the Forward Probability of Contamination (P_C)

323D | Project Systems Engineering; presented by Michael DiNicola
Jet Propulsion Laboratory, California Institute of Technology

Jet Propulsion Laboratory
California Institute of Technology

This document has been reviewed and determined not to contain export controlled technical data.
© 2026 California Institute of Technology. Government sponsorship acknowledged.

MOTIVATION

Forward planetary protection addresses the risk of contaminating non-Earth bodies with terrestrial organisms.

NASA planetary protection policy requires that the probability of biological contamination be reduced to acceptable levels, especially for missions exploring potentially habitable planetary bodies or those with life-detection objectives.

Robotic missions going back to Mariner, Pioneer and Viking handled this with a mix of modeling and bioburden reduction protocols during development that fed into a probability of contamination model.

Over time planetary protection requirements for Mars missions became more prescriptive, requiring flight projects to demonstrate compliance with bioburden constraints via spacecraft sampling.

As NASA expands into commercial partnerships and the prospect of human exploration of Mars, a model-based framework is coming back to the forefront

- Better scope planetary protection protocols
- Enable projects to evaluate alternative compliance strategies while maintaining policy requirements

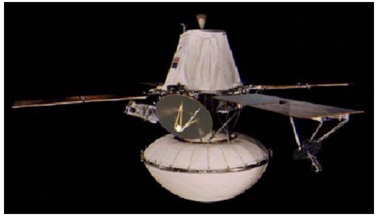
We have had success applying this modeling to Europa Clipper and Europa Lander

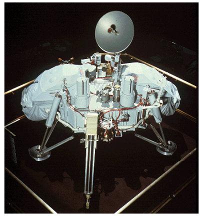
THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

MISSIONS WE WILL LOOK AT TODAY

Viking

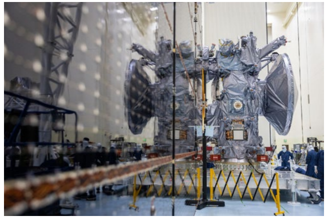
- Two missions to Mars: Viking 1, Viking 2
- Launched August–September 1975 on Titan IIIE launch vehicles
- Each mission included an orbiter & lander
- Conducted three life-detection experiments on Mars
- Produced the first high-res global maps
- Final transmissions: Viking 2 (1980), Viking 1 (1982)

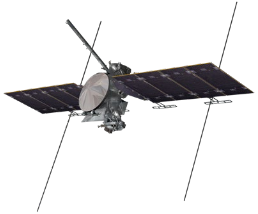




Europa Clipper

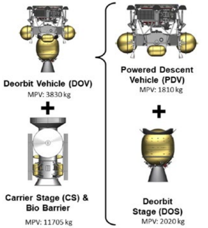
- Launched October 2024 on Falcon Heavy launch vehicle
- Single orbiter; largest planetary S/C
- Will perform 49 close flybys of Europa in orbit around Jupiter
- 10 instrument payload to study geology, ice shell and magnetic field
- Jupiter Orbit Insertion: April, 2030
- 4+ year tour planned

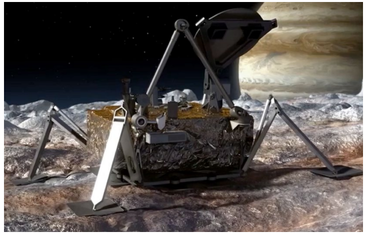




Europa Lander

- Concept in development prior to 2020
- Lander & orbiter flight system
- In situ instruments to detect biosignatures, assess habitability, and characterize the subsurface
- 2-3 month planned surface operations
- Included a Terminal Sterilization System (TSS) to incinerate lander at EOM





THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

MARS VS. EUROPA MODEL APPROACH TO P_C

	Mars	Europa
Failure Concerns	• Maneuverability; Separation during EDL	• Maneuverability; Separation during DDL; PP hardware
Engineering	• Single and multiple flight elements • Orbital flybys; Entry, Descent, Landing Ops • Nuclear (RTGs) and solar power • Mobile systems	• Single and multiple flight elements • Orbital flybys; Deorbit, Descent, Landing Ops • Solar Powered (no nuclear material, yet) • Heavily shielded electronics vaults
Transport	• Mars atmosphere, wind, weather, rover • Ice present with geology that is better understood relative to Europa	• No significant atmosphere • Geological resurfacing processes not well understood • Ice shell, subsurface ocean hypothesized
Habitability	• Special regions, water activity, temperature	• Subsurface assumed habitable (conservative)
Biological	• Spores only have been the focus • UV lethality	• Total viable organisms • Ionizing radiation
Policy	Period of Biological Exploration: Launch + 50 years	Period of Biological Exploration: from now to the year 3000
Mathematical	• Coleman-Sagan approximation • Survival and release probabilities not based on trajectory properties • Lethality not fully considered across the S/C	• Independence assumptions and incorporation of trajectory information • Rigorous mathematics • Detailed bioregions accurately capture lethality

© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

WHAT DOES "CONTAMINATION" MEAN FOR MARS MISSIONS?

Icy Bodies RQ

The probability of *inadvertent* contamination of an *ocean or other liquid water body* shall be less than 1 x 10^{-4} per mission.

Mars Adaptation

The probability of *harmful* contamination of a potentially *habitable Martian environment* shall be less than 1 x 10^{-4} per mission.

The calculation of this probability shall include a conservative estimate of poorly known parameters, and address the following factors, at a minimum:

- Bioburden at launch
- Cruise survival for contaminating organisms
- Organism survival in the radiation environment adjacent to the target [Mars]
- Probability of encountering/landing on the target [Mars], including spacecraft reliability
- Probability of surviving landing/impact on the target [Mars]
- Mechanisms and timescales of transport to the subsurface [a potentially habitable environment]
- Organism survival and proliferation within a specified period of biological exploration

THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

VIKING MISSIONS

Modeling Approach: Simple Coleman-Sagan approximation

Project Challenges: Maintain scientific integrity of life detection experiments.

Key Model Relationships: Terms multiplicative; implicit independence assumptions & traceability of certain probabilities flagged as a concern

Drivers: Probability of growth & encapsulated bioburden, sterilization

$$P_C = \sum_{q=1}^{Q} \sum_{b=1}^{B_q} \Pr[I_q] \times \Pr[C_b|I_q]$$

Q: # of flight elements; B_q: # of bioburden regions on flight element q

$$\Pr[C_b|I_q] \approx N_{0,b,q} \times \Pr[r_b|I_q] \times \Pr[s_b|I_q \cap r_b] \times \Pr[g|I_q \cap r_b \cap s_b]$$

	Spore Burden prior to Terminal Sterilization and FAT	Prob of Impact, $\Pr[I_q]$	Prob Individual Spore is Released given Impact	**Prob Individual Spore survives given Release & Impact	Prob Individual Spore Proliferates given Survival, Release & Impact	$P_C = \sum \Pr[C_b \mid I_q]$ (Recalc)
Viking A	*	-	-	-	-	**5.55E-05**
LV Lower Stages + Centaur + Shroud + Bioshield Base	*	0	-	-	-	0
Bioshield Cap	**5.66E+06**	-	-	-	-	**1.36E-05**
Surface	1.62E+05	1.00E-02	5.00E-01	1.00E-01	1.00E-06	8.10E-06
Mated	6.00E+02	1.00E-02	1.00E-01	1.00E-03	1.00E-06	6.00E-10
Encapsulated	5.50E+06	1.00E-02	1.00E-04	1.00E+00	1.00E-06	5.50E-06
Viking Orbiter	*	**3.23E-05**	-	-	-	**3.23E-05**
VLC	**1.43E+07**	-	-	-	-	**1.12E-06**
Surface & Insulation	2.53E+05	1.00E+00	1.00E+00	7.24E-12	1.00E-06	1.83E-12
Mated	2.94E+03	1.00E+00	2.00E-03	1.45E-06	1.00E-06	8.55E-12
Pseudo-Mated	1.71E+01	1.00E+00	1.00E+00	2.71E-06	1.00E-06	4.63E-11
Encapsulated	1.40E+07	1.00E+00	1.00E-04	6.25E-04	1.00E-06	8.76E-07
Recontamination	3.62E+04	1.00E+00	1.00E-04	6.82E-02	1.00E-06	2.47E-07
Ejecta-Efflux	-	-	-	-	-	**8.53E-06**

*Assumed dirty; not bounded - N/A or unavailable

** Includes the probability that a spore survives Terminal Sterilization & Flight Acceptance Testing (FAT)

THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

EUROPA CLIPPER MISSION

Modeling Approach: Rigorous probabilistic model

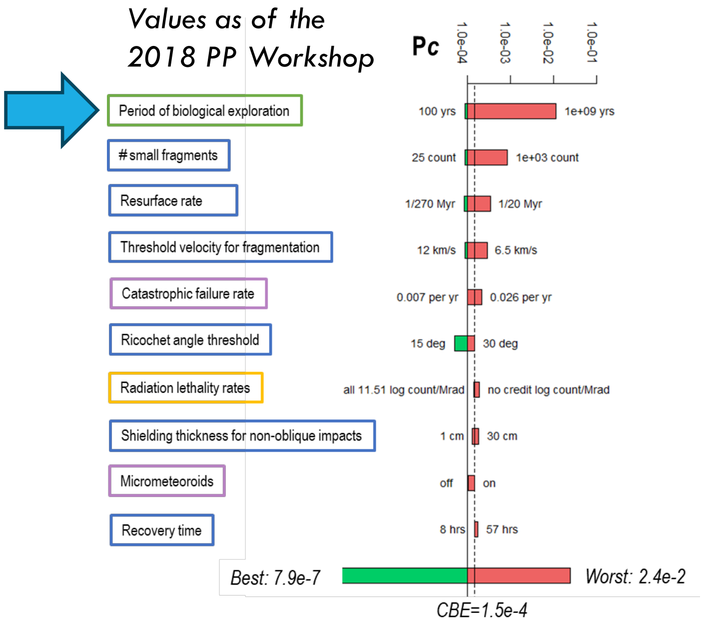
$$P_C = \sum_{n=1}^{N} \Pr[I_n] \times \Pr[R_t | I_n] \times \Pr[S \,| R_t \cap I_n]$$

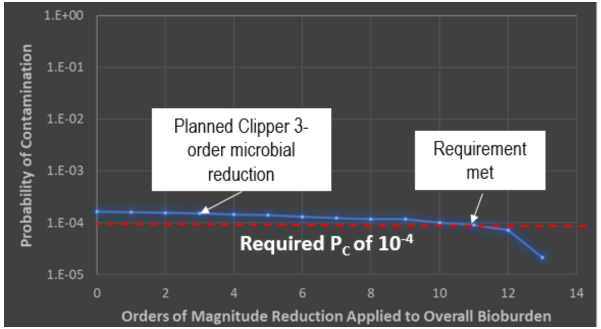
Project Challenges: What bioburden reduction is needed and what hardware should be selected?

Key Model Relationships:

- Non-linear survival term that behaves like $1-(1-s)^{N_0}$
- Coupled with high bioburden on any one piece of h/w
- Gives a P_C that plateaus & bottlenecks

Drivers: Period of biological exploration, debris and resurfacing parameters, shallow angle impacts





THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

EUROPA LANDER CONCEPT

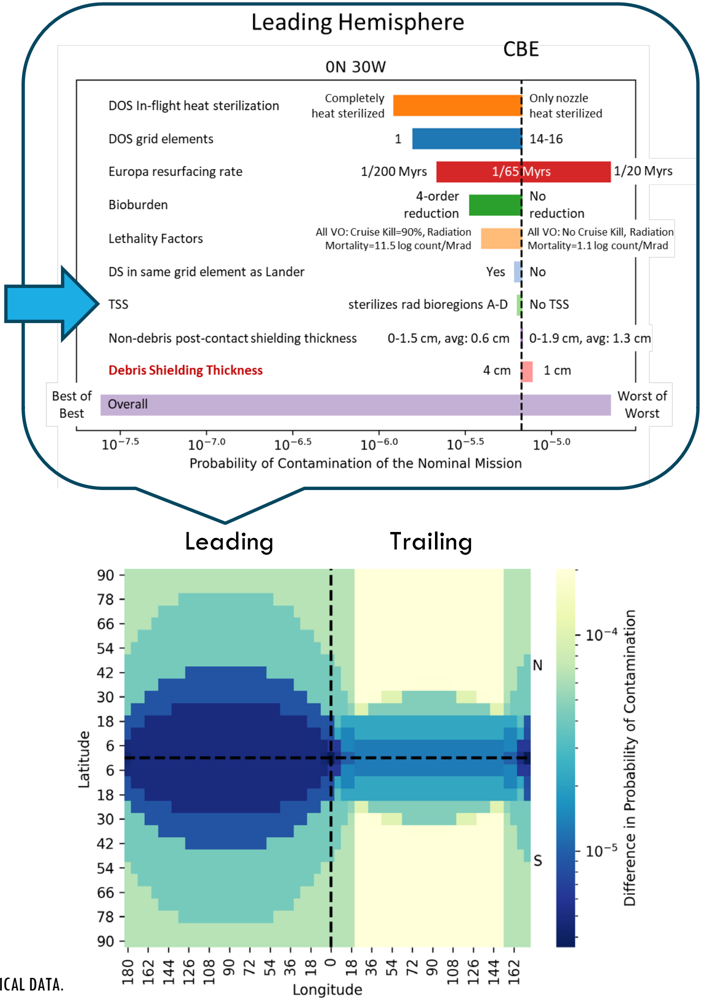
Modeling Approach: Clipper approach expanded for multiple flight elements

Project Challenges: Are a biobarrier and new tech TSS necessary? If a TSS is needed, how much energetic?

Key Model Relationships:

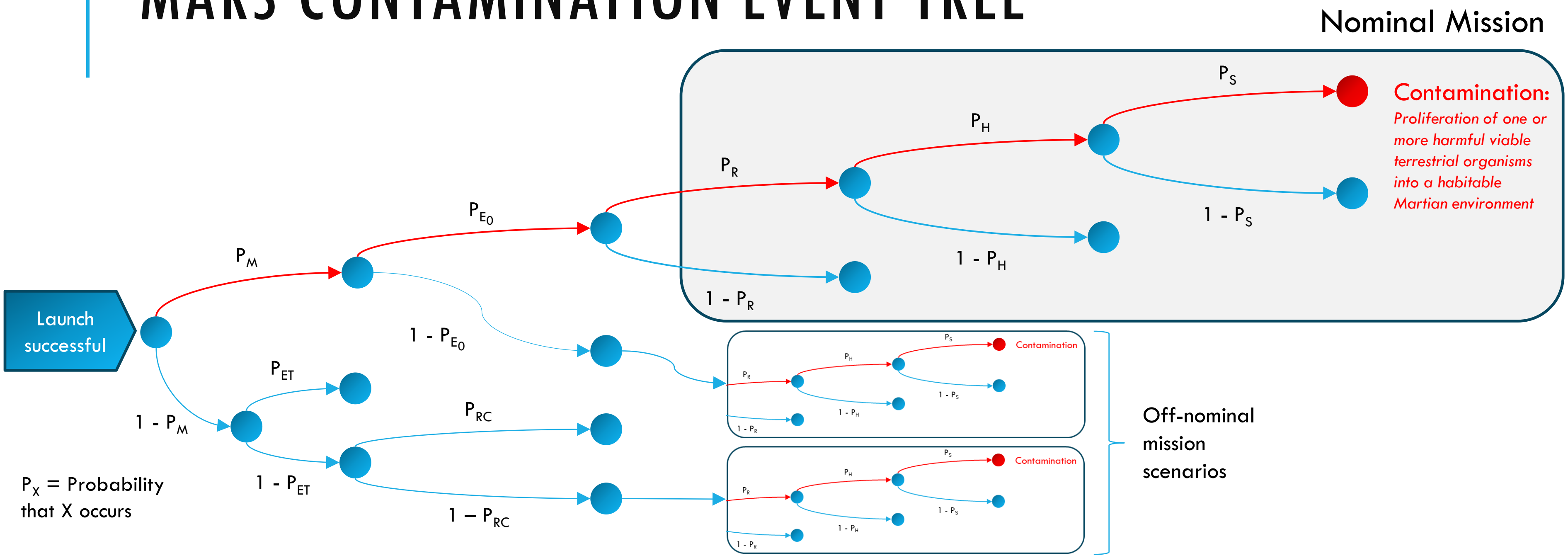
- P_C that plateaus & bottlenecks (as with Clipper)
- Impactables have a greater influence on P_C than lander
- PP affects landing site selection and science

Drivers: Solid Rocket Motor (jettisoned after deorbit), debris and resurfacing parameters, shallow angle impacts



THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

MARS CONTAMINATION EVENT TREE



M: All Maneuvers & Separation Events Successful

ET: On an Entry Trajectory

E$_0$: Nominal Mission Successful

RC: Recover to Avoid Entry

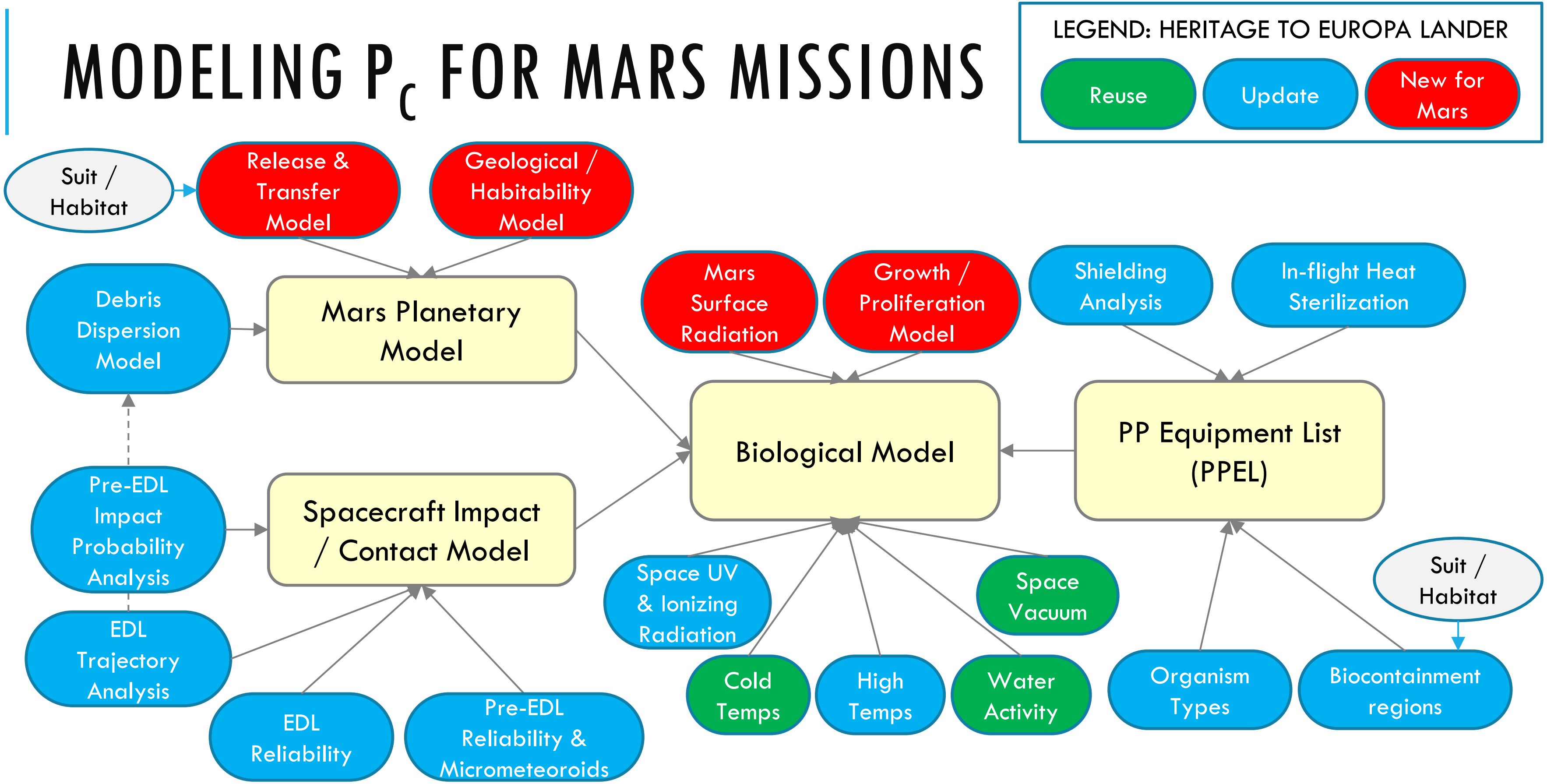
R: Some Particle Hosting VO Released into the Mars Environment

H: Some Particle Transports to a Habitable Region of Mars

S: Some particle Remains Unsterilized and a VO proliferates

S BEEN 2026 C N EXP VERNMEN

MODELING P_C FOR MARS MISSIONS



THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

CONCLUDING REMARKS AND PATH FORWARD

A model-based framework

- Allows projects to better scope planetary protection protocols
- Enables projects to evaluate alternative compliance strategies while maintaining policy requirements

This modeling has helped projects make big decisions

- Clipper: Large scale bioburden reduction measures would not have significantly reduced the contamination risk
- Clipper: Defining a period of biological exploration was imperative
- Europa Lander: Terminal Sterilization System (and biobarrier) not necessary to satisfy PP RQ
- Europa Lander: Significant PP risk comes from SRM jettisoned at deorbit, not lander; PP affects landing site

Developing this model framework to evaluate Mars missions

- Currently evaluating the Viking mission as a starting point
- Looking forward to having model machinery up and running by end of FY 2026

THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

BACKUP

- Mathematical Architecture
- Path Forward
- Viking Literature Review & Associated Analysis
- Europa Clipper Sensitivities Reported in 2020 PRA
- Additional Europa Lander Sensitivity Analysis
- References
- Abstract

THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

VIKING PROBABILISTIC MODEL

Event that the Actual Viking Mission occurs

Probability that the spacecraft has an initial particle count, N, and associated bioload, n_0

Probability density associated with particle size (diameter)

Probability an individual particle of diameter δ with bioload n_0 contaminates Mars

Probability of Contamination of an Individual Viking Mission

$$P_{C|E_0} = \sum_{N,\text{n}} \Pr[N, \text{n}_0 \mid E_0] \times \left[1 - \prod_{i=1}^{N} \left(1 - \int_{\delta} f(\delta) \Pr[C_i \mid \delta, \text{n}_0, E_0]\, d\delta\right)\right]$$

End of the Period of Biological Exploration

Probability density associated with particle time of release

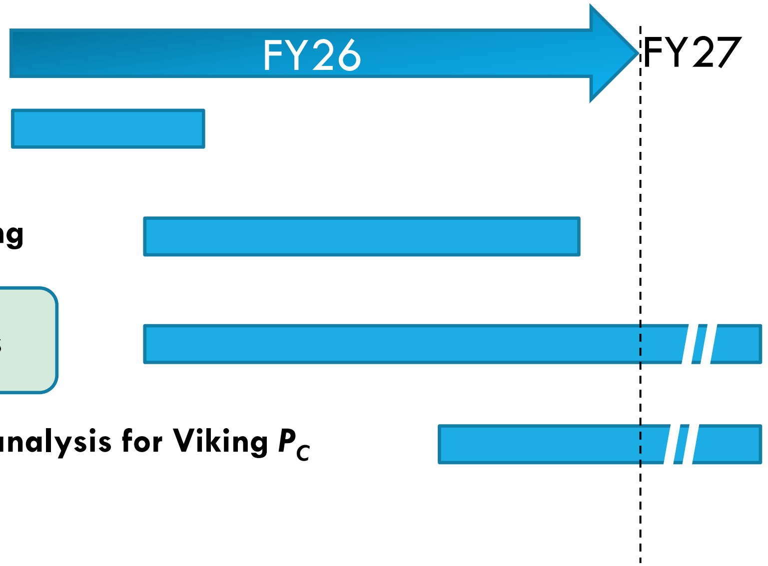
Probability a particle remains unsterilized and proliferates after transports to a habitable environment

$$\Pr[C_i \mid \delta, \text{n}_0, E_0] = \int_{t_0}^{\tau} f_{T_R}(t) \Pr[H_\tau \mid T_R = t] \times \Pr[S_i \mid H_\tau, T_R = t]\, dt$$

Probability a released particle transports to a habitable environment

THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

GOAL FOR FY26



- **Formulate Mathematical Model for Viking P_C**
- **Adapt Europa Lander P_C model infrastructure to Viking**
- **Gather needed inputs for model**

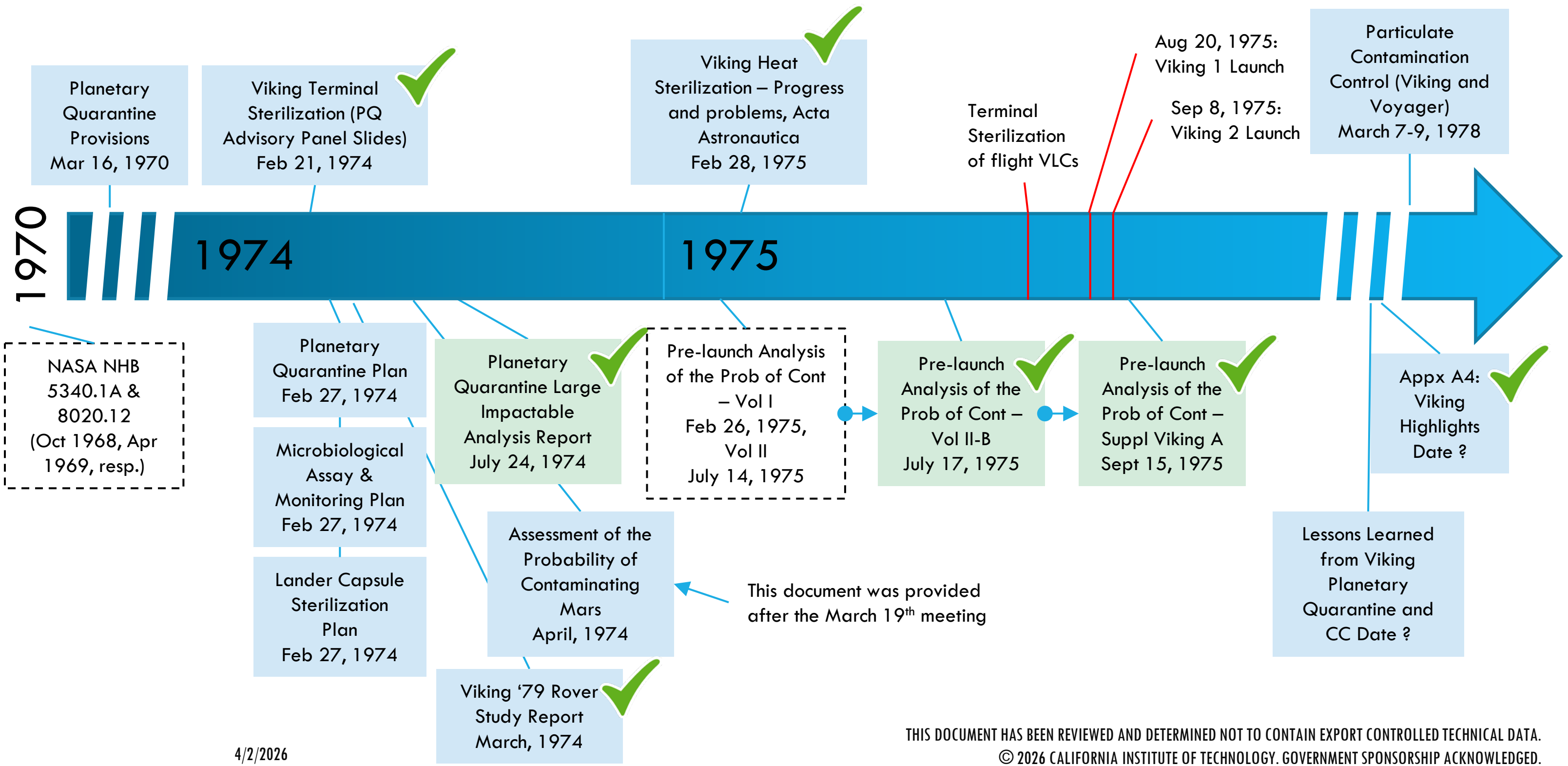
Engage SMEs

- **Perform model V&V and run use cases / sensitivity analysis for Viking P_C**

Adapt EL model to Viking by end of FY26 - Mars planetary model development will go into FY27

THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

DOCUMENT REVIEW



THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

VIKING PLANETARY PROTECTION IMPLEMENTATION APPROACH

The entire Viking Lander Capsule (VLC) will be dry heat sterilized, within a bioshield, prior to launch.

The **bioshield** shall be continuously maintained at a static pressure of 5.0 inches of water above the ambient pressure **from terminal sterilization to launch.**

Aim point biasing and deflection maneuver will be utilized to satisfy the **contamination** probability associated with the **launch vehicle.**

Aim point biasing for midcourse maneuver will place the **spacecraft** in a trajectory **consistent with Planetary Quarantine constraints.**

Orbit insertion and orbit trim maneuvers will place the spacecraft into an orbit **consistent with the PQ constraints.**

Cleaning methods, as well as procedural and facility controls, will be employed during the assembly and test of the flight articles.

Biological assays will be performed at pertinent times during flight spacecraft assembly and test as specified in the Viking 75 Program Microbiological Assay and Monitoring Plan, M75-148.

A planetary quarantine mathematical model will be developed and utilized to allocate and estimate the contamination probabilities associated with each potential biological contamination source and/or event."

Requirement	Viking[1]	Comment
Part/Material Qualification[1]	*Performed on samples from flight lot* *Non-Operating (if required)*: 125-135 deg C (± 2 deg C), 1000 hours *Operating*: TBD deg C (± 2 deg C), "Elevated T", 1000 - 2000 hours	• Qual Temp - 155 deg C at start, backed off to 135 deg C then 125 deg C (Ref V2 Pg. 2.4, 2.5). 125 deg C consistent with MIL Standard temp for most parts (was becoming a standard around that time). Thermocouple uncertainty ± 2 deg C at temps in this range (Ref V2, Pg 2.8, implied) . • Qual Time - 1000 hours consistent with MIL Standard for active parts (believe requirement shown did not include passives). Backed off to 1000 hours for many parts (TBD Ref)
Part/Material Acceptance[1]	TBD - probably did screening	
Component Qualification[1]	*Performed on Qual Unit for Components* 111.7 deg C (± 1.7), 54 hours 123 deg C (± 2), 8 X 54 hours	• Qual Temp - 125 deg C was the max temp reasonable for most components/parts (Ref V2, Pg 3.22). Backed off 2 degrees C to account for thermocouple errors (Ref V2, Pg 2.8, implied) (125 - 2 = 123) • Qual Time/Cycles - 2X time at temperature on flight unit [(com accept (1) + system accept (1) + sterilization (1) + rework (1)] x 2 = 8.
Component Acceptance[1] **(& encapsulated burden reduction)**	*Performed on Flight Unit and Spare for Components* 111.7 deg C (± 1.7), 54 hours	• Acceptance Temp - Project requirement was for a minimum 10 deg C margin between the Qual and Acceptance levels (Ref V2, Pg 3.22). Accounted for thermocouple errors (Ref V2, Pg 2.8, implied) ((123 - 2)- 10 - (+1.7) = 112.7) • Acceptance Time - 54 hours is ~1/2 the time required to reduce encapsulated bioburden by 4 orders of magnitude at ~112 deg C. Assumes other 1/2 time accomplished during System Acceptance or System Sterilization (speculation).
System Qualification[1]	*Performed on TETM & PTC* 111.7 deg C (± 1.7), 35 hours[2] 123 deg C (± 2), 40 hours[2], 40 hours[2]	• Qual Temp - See component comments above for the Qual temperature levels. • Qual Time/Cycles - Wanted to verify system could withstand at least 3 cycles (1 for Acceptance + 1 for System Sterilization + 1 recycle if required) (Ref V5, pg 21).
System Acceptance[2] **(performed?)**	*Performed on Flight Unit* 111.7 deg C (± 1.7), TBD hours	• Accept Temp - See component comments above for the Acceptance temperature levels. • Accept Time - TBD. Cycle time reduced from 54 hours due to the actual cleanliness levels achieved and the expected reduced terminal sterilization time (speculation).
System Sterilization	*Performed on Flight Unit (Non-Operating)* 112 deg C (± 1.7), ~ 30 hours (VLC-1), 23 hours (VLC-2)	• Temp - See comments above for the temperature level. • Time - Sterilization time was selected and minimized based on actual bioburden estimates.

[1]"Lessons Learned from the Viking Planetary Quarantine and Contamination Control Experience", NASW-4355, Pg 2.8, The Bionetics Corporation, MSS Ref V2.
[2]"Viking '75 Program Lander Capsule Sterilization Plan, M75-147-0, February 27, 19974, LaRC, MSS Ref V5. Unknown if test actually performed.

THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

VIKING PROBABILITY OF CONTAMINATION CALCULATION

Total Viking Mission P_C

$$P_C = P_{C,1} + P_{C,2}$$

- $P_{C,1}$: P_C of Viking A
- $P_{C,2}$: P_C of Viking B

$$P_{C,i} = \sum_{q=1}^{Q} \sum_{b=1}^{B_q} \Pr[I_{q,i}] \times \Pr[C_b | I_{q,i}]$$

- Q: # of flight elements on Viking i
- B_q: # of bioburden regions on flight element q
- $\Pr[I_{q,i}]$: Probability that flight element q of Viking i impacts/contacts Mars
- $\Pr[C_b | I_{q,i}]$: Probability that region b of flight element q of Viking i contaminates Mars, given impact

$$\Pr[C_b | I_{q,i}] = N_{0,b,q,i} \times \Pr[r_b | I_{q,i}] \times \Pr[s_b | I_{q,i} \cap r_b] \times \Pr[g | I_{q,i} \cap r_b \cap s_b]$$

- $N_{0,b,q,i}$: Spore Burden at Launch
- $\Pr[r_b | I_{q,i}]$: Probability Individual Spore is Released given Impact
- $\Pr[s_b | I_{q,i} \cap r_b]$: Probability Individual Spore survives given Release & Impact
- $\Pr[g | I_{q,i} \cap r_b \cap s_b]$: Probability Individual Spore Proliferates (Grows) given Survival, Release & Impact

THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

VIKING P_C

All results here use the Viking calculation approach (which is an approximation to P_C at best)

The Viking Missions have a total P_C allocation of 2×10^{-4}.

Recalculation of P_C using document sources results in a value slightly higher than that calculated by the project due to estimated Bioshield Cap volume and its resulting bioburden

Removing the reductions given by Terminal Sterilization (but retaining those from the Flight Acceptance Testing), P_C is very high: 0.5 >>10^{-4}

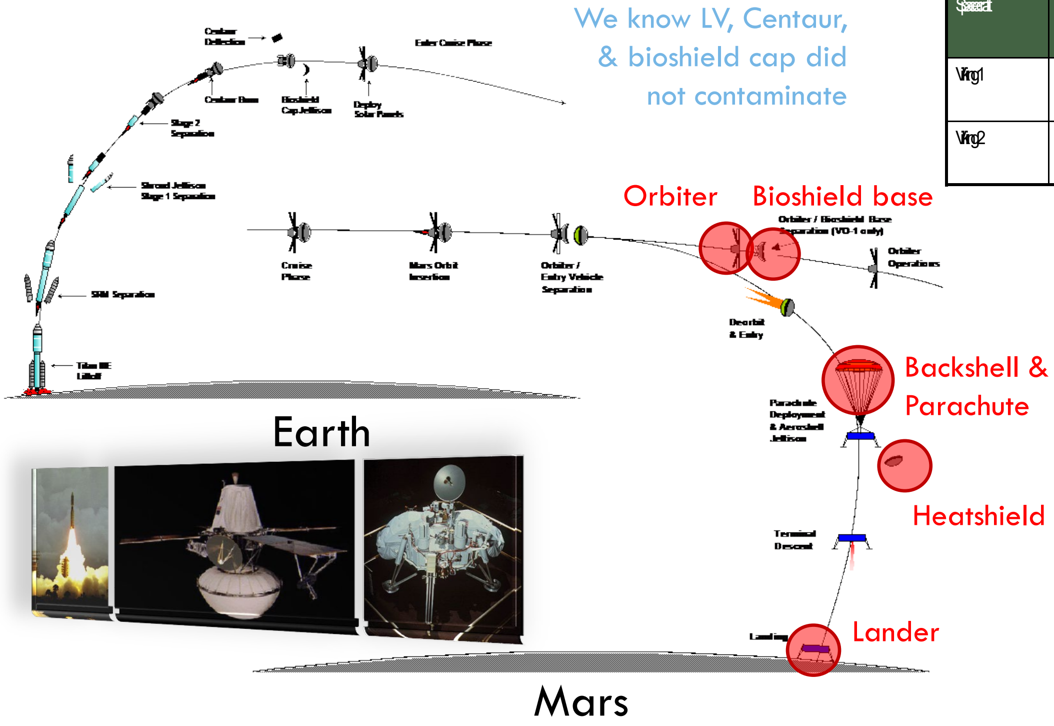
*Assumed dirty; not bounded
- N/A or unavailable

**includes the probability that a spore survives Terminal Sterilization & Flight Acceptance Testing (FAT)

	Spore Burden prior to Terminal Sterilization and FAT	Probability of Impact	Probability Individual Spore is Released given Impact	**Probability Individual Spore survives given Release & Impact	Probability Individual Spore Proliferates (Grows) given Survival, Release & Impact	P_C (Recalc)	P_C (Project)	P_C (w/o Terminal Sterilization)	P_C Project Allocation
Viking Mission	*	-	-	-	-	**1.11E-04**	**1.02E-04**	**5.07E-01**	**2.00E-04**
Viking A	*	-	-	-	-	**5.55E-05**	**5.10E-05**	**2.54E-01**	**1.00E-04**
LV Lower Stages	*	0	-	-	-	0	0	0	
LV Centaur Stage	*	0	-	-	-	0	0	0	
LV Fairing / Shroud	*	0	-	-	-	0	0	0	
Bioshield Cap	**5.66E+06**	-	-	-	-	**1.36E-05**	**9.00E-06**	**8.71E-05**	
Surface	1.62E+05	1.00E-02	5.00E-01	1.00E-01	1.00E-06	8.10E-06	8.00E-06	8.10E-05	
Mated	6.00E+02	1.00E-02	1.00E-01	1.00E-03	1.00E-06	6.00E-10	6.00E-10	6.00E-07	
Encapsulated	5.50E+06	1.00E-02	1.00E-04	1.00E+00	1.00E-06	5.50E-06	1.00E-06	5.50E-06	
Bioshield Base	*	**0**	-	-	-	**0**	**0**	**0**	
Viking Orbiter	*	**3.23E-05**	-	-	-	**3.23E-05**	**3.23E-05**	**3.23E-05**	
VLC	**1.43E+07**	-	-	-	-	**1.12E-06**	**1.12E-06**	**2.53E-01**	**2.00E-05**
Surface & Insulation	2.53E+05	1.00E+00	1.00E+00	7.24E-12	1.00E-06	1.83E-12	1.83E-12	2.53E-01	
Mated	2.94E+03	1.00E+00	2.00E-03	1.45E-06	1.00E-06	8.55E-12	8.56E-12	5.88E-06	
Pseudo-Mated	1.71E+01	1.00E+00	1.00E+00	2.71E-06	1.00E-06	4.63E-11	4.63E-11	1.71E-05	
Encapsulated	1.40E+07	1.00E+00	1.00E-04	6.25E-04	1.00E-06	8.76E-07	8.74E-07	1.03E-04	
Recontamination	3.62E+04	1.00E+00	1.00E-04	6.82E-02	1.00E-06	2.47E-07	2.47E-07	3.62E-06	
Ejecta-Efflux	-	-	-	-	-	**8.53E-06**	**8.53E-06**	**8.53E-06**	**2.80E-05**
Viking B			**assumed the same as Viking A**			**5.55E-05**	**5.10E-05**	**2.54E-01**	**1.00E-04**

THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

MISSION OVERVIEW



See map in backup

Spacecraft	Launch Date (Orbiter+Lander)	Launch Vehicle/ Site	Landing Date	Location
Viking 1	August 20, 1975	Titan IIIE/ Cape Canaveral	July 20, 1976	Chryse Planitia 22.4 °N, 47.5 °W
Viking 2	September 9, 1975	Titan IIIE/ Cape Canaveral	September 3, 1976	Utopia Planitia 48 °N, 226 °W

- The last data from Viking Lander 2 arrived at Earth on April 11, 1980. Viking Lander 1 made its final transmission to Earth November 11, 1982.
- Photographed and other science data on the Martian surface
- Conducted three biology experiments designed to look for possible signs of life.
    - Discovered unexpected and enigmatic chemical activity in the Martian soil, but provided no clear evidence of life

THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

EUROPA CLIPPER MISSION

Modeling Approach: Rigorous probabilistic model

$$P_C = \sum_{n=1}^{N} \Pr[I_n] \times \Pr[R_t | I_n] \times \Pr[S \,| R_t \cap I_n]$$

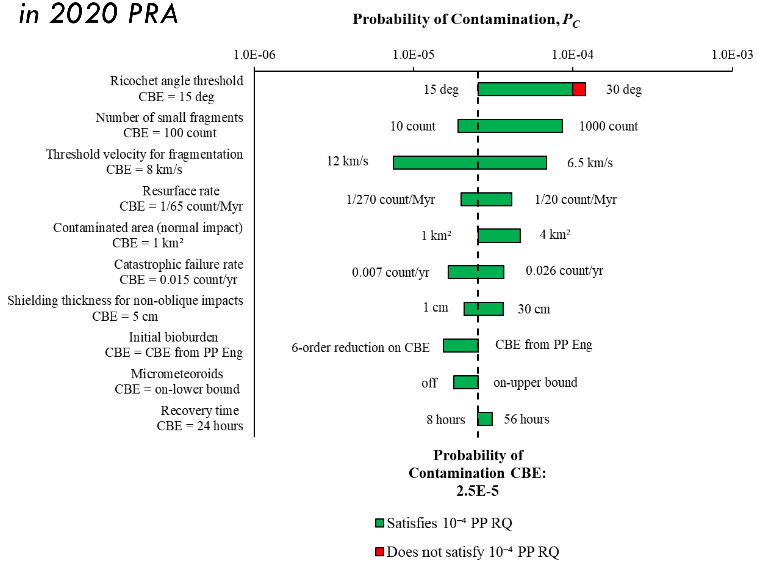
Project Challenges: What bioburden reduction is needed and what hardware should be selected?

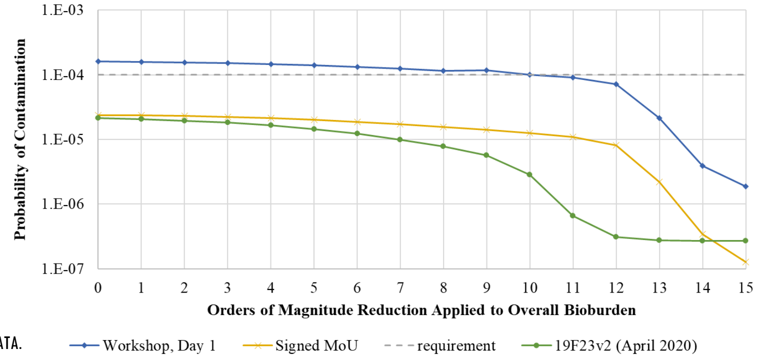
Key Model Relationships:

- Non-linear survival term that behaves like $1 - (1 - s)^{N_0}$
- Coupled with high bioburden on any one piece of h/w
- Give a P_C that plateaus & bottlenecks

Drivers: Period of biological exploration, debris/resurfacing parameters, shallow angle impacts

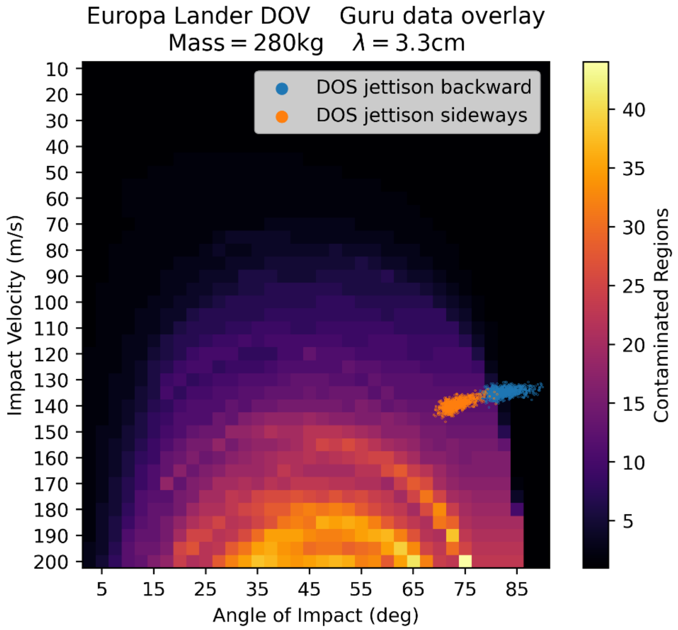
Values reported in 2020 PRA

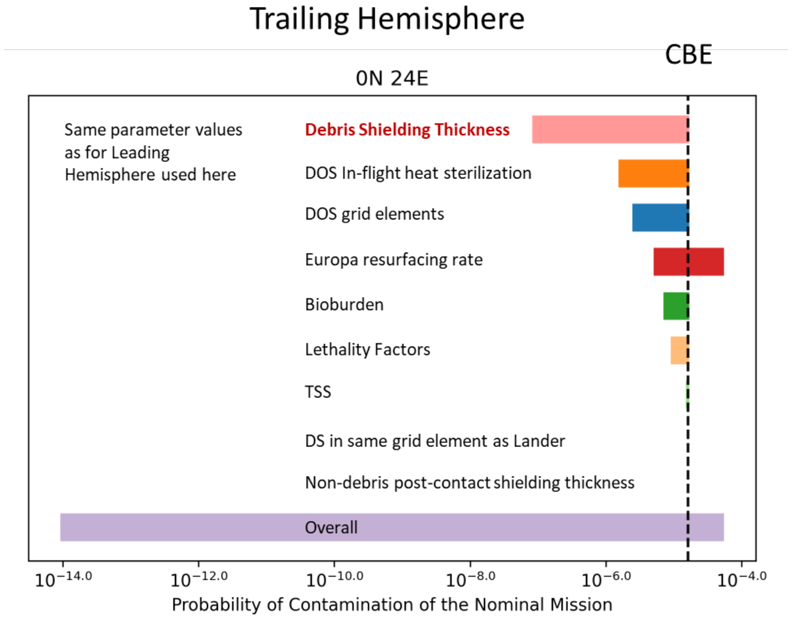




THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

ADD'L EUROPA LANDER SENSITIVITY ANALYSIS





THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

REFERENCES (1/2)

1. Viking 75 Program, NASA Langley Research Center, Viking Project Office. ***Planetary Quarantine Provisions***, Document ID: M75-127-1, Report Date: March 16, 1970, Revision Date: August 16, 1971
2. Viking Project, Planetary Quarantine Advisory Panel. ***Viking Terminal Sterilization***, Report Date: February 21, 1974
3. Viking 75 Program, NASA Langley Research Center, Viking Project Office. ***Planetary Quarantine Plan***, Document ID: M75-149-0, Approval Date: February 27, 1974
4. Viking 75 Program, NASA Langley Research Center, Viking Project Office. ***Microbiological Assay and Monitoring Plan***, Document ID: M75-148-0, Approval Date: February 27, 1974
5. Viking 75 Program, NASA Langley Research Center, Viking Project Office. ***Lander Capsule Sterilization Plan***, Document ID: M75-147-0, Approval Date: February 27, 1974
6. Martin Marietta Aerospace, Denver, CO. ***Viking '79 Rover Study – Final Report***, Contract NAS1-12425, Report Date: March, 1974
7. Stanford Research Institute, prepared by Dodd, B.R.; North, D. W.; Pezier, J.P. ***Assessment of the Probability of Contaminating Mars – Final Report***, NASA Contract NASW-2535, SRI Project MSU-2788, Report Date: April, 1974

THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.

REFERENCES (2/2)

8. Jet Propulsion Laboratory, California Institute of Technology. ***Viking planetary Quarantine Large Impactable Analysis Report***, Document ID: 611-108, Report Date: July 24, 1974
9. Daspit, L.P.; Stern, J.A.; Cortright, E.M. **Viking heat sterilization – progress and problems.** Acta Astronautica, Vol 2, pp. 649-666, Received: February 28, 1975
10. Viking 75 Program, NASA Langley Research Center, Viking Project Office; prepared by Nelson, B. A. under contract NAS1-9000 at Martin Marietta, Denver, CO. ***Pre-launch Analysis of the Probability of Planetary Contamination***, Volume II-B (VLC-1), Document ID: M75-155-0-2. PR-3701060-1A. Approval Date: July 17, 1975
11. Viking 75 Program, NASA Langley Research Center, Viking Project Office; prepared by Nelson, B. A. and Hoffman, A. R. under contract NAS1-9000 at Martin Marietta, Denver, CO. ***Pre-launch Analysis of the Probability of Planetary Contamination Supplement***, S/C-B (Viking Mission A), Document ID: M75-155-0-4. PR-3701060-2A. Approval Date: September 15, 1975
    - Two versions of this document were provided, the difference being an Appendix that includes the **Viking Orbiter 1975 Input to the Viking Integrated Planetary Quarantine Plan** from July 10, 1970.
12. The Bionetics Corporation; prepared under contract NASW-4355. ***Lessons Learned from the Viking Planetary Quarantine and Contamination Control Experience.*** No report date provided.
13. Hoffman, A. R.; Koukol, R. C. **Particulate Contamination Control for the Viking and Voyager Unmanned Planetary Spacecraft.** Proceedings of the USAF/NASA International Spacecraft Contamination Conference, ed. Jemiola, J. M., AFML-TR-78-190 or NASA-CP-2039, pp. 899-926. Presented at this conference in Colorado Springs, CO, March 7-9, 1978
14. **Appendix A4: Viking Highlights.** No authorship provided; summarizes information from some of the documents above.

THIS DOCUMENT HAS BEEN REVIEWED AND DETERMINED NOT TO CONTAIN EXPORT CONTROLLED TECHNICAL DATA.
© 2026 CALIFORNIA INSTITUTE OF TECHNOLOGY. GOVERNMENT SPONSORSHIP ACKNOWLEDGED.