Mars Sample Return: End to End Curation from Return to Earth to Sample Distribution – Report from iMARS Phase II

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iMARS – Background

- **i**nternational **M**ars **A**rchitecture for the **R**eturn of **S**amples
- Originally chartered by IMEWG in 2006 to develop a plan for Mars Sample Return Mission Architecture

iMARS Phase I – Recommendations

"IMSI" Concept

- Multinational mission will require multinational coordination to accomplish
  - ***Need to define an International MSR Science Institute***

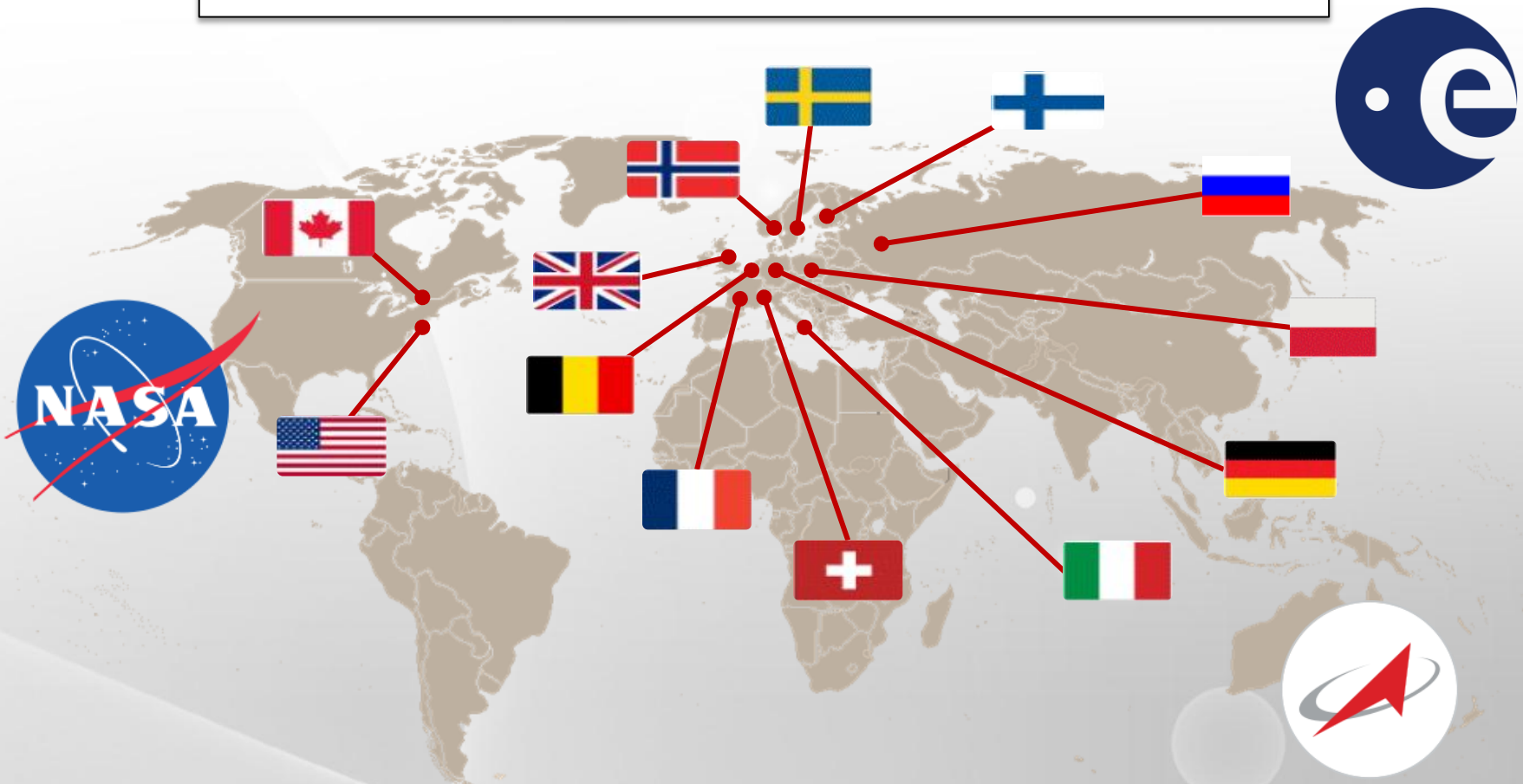
Distributed vs. On Site Needs

- Not everyone with an excellent science investigation would be able to work at the return facility
  - ***How do we keep the samples from becoming "stuck in containment?"***

Roster

Steering Committee

Lisa May → Dave Lavery	Rolf de Groot	Lev Zelenyi



Lessons From Previous Sample Return Missions

IODP
INTERNATIONAL OCEAN DISCOVERY PROGRAM

Storage / Quarantine / Curation

- No quarantine or planetary protection since Apollo

Preliminary Examination

- Detailed investigation flow based on sample suite

Sample Return Facility

- Sets expectation for level of technology found behind containment

Technical Support

- Staffing and institutional needs

Planetary Protection Considerations

Avoiding the "Stuck in Containment" scenario

- Aim is to make samples available to community as soon as it is safe to do so

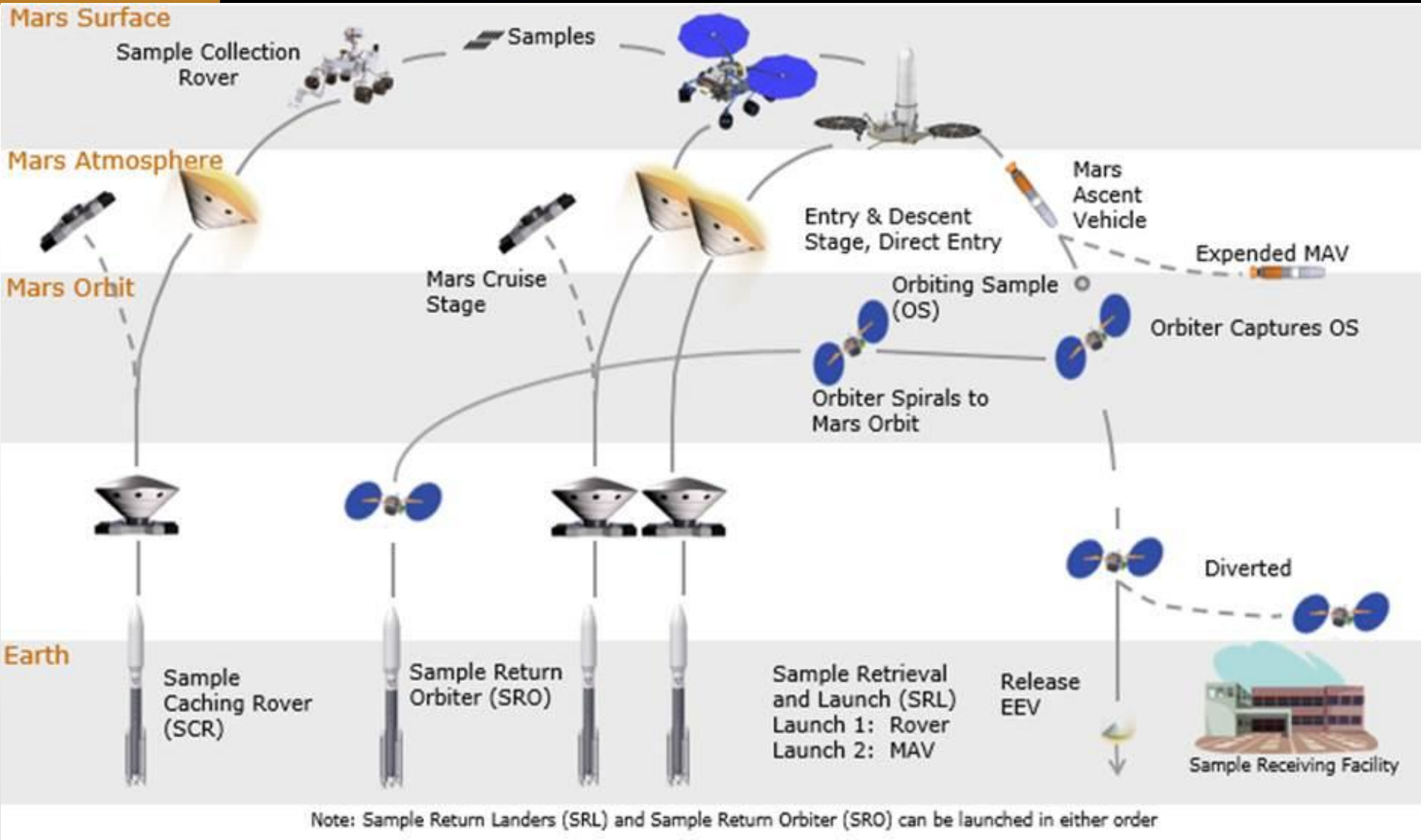
"Science" and "Safety" are actually complementary

- Many investigations will meet objectives of both

Rolling release may be possible

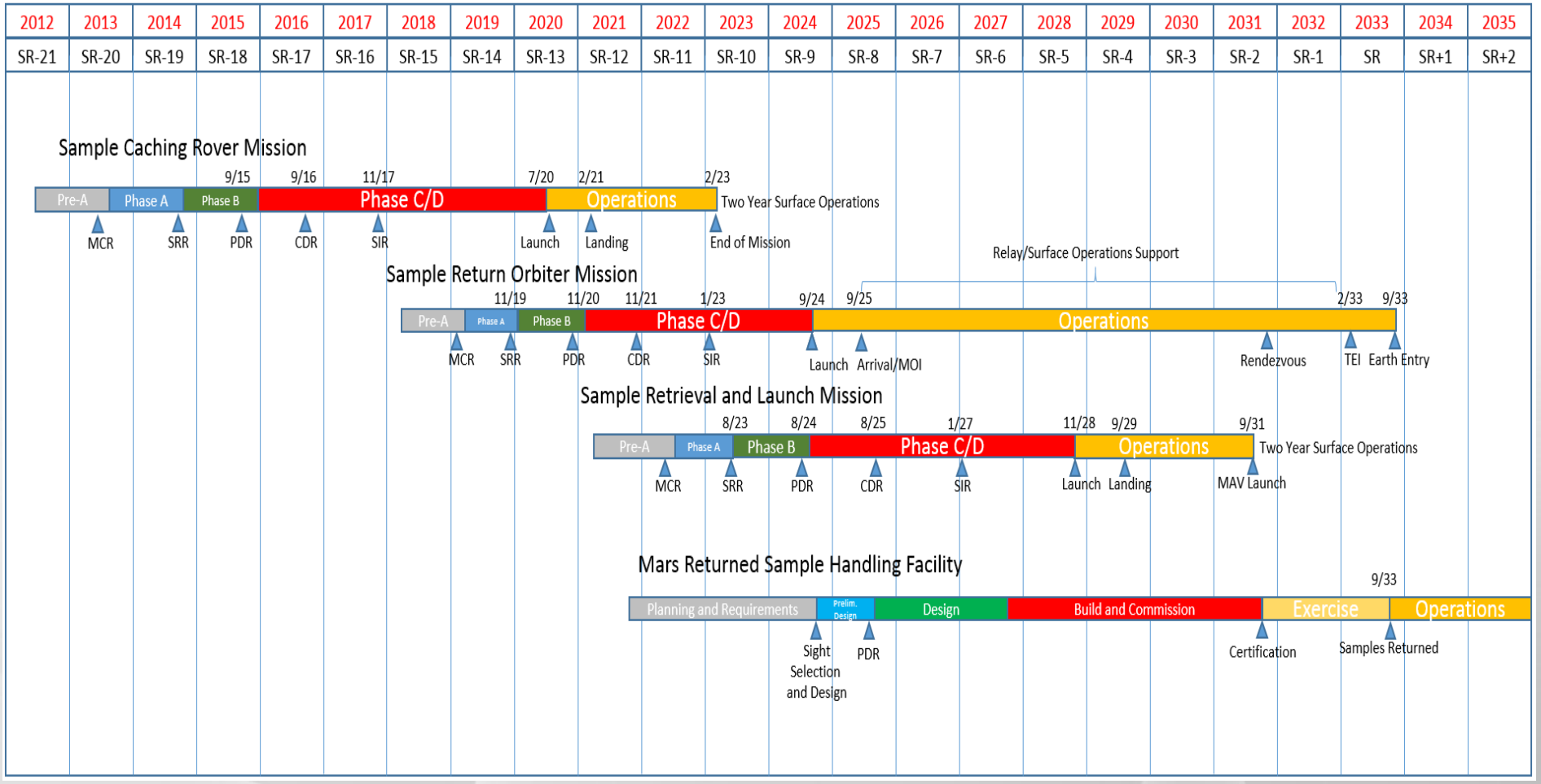
- Samples that are deemed 'safe' (through protocol or sterilization) can be allocated to community early on
- Some samples will understandable require extensive investigation

Alternative MSR 4+1 Architecture

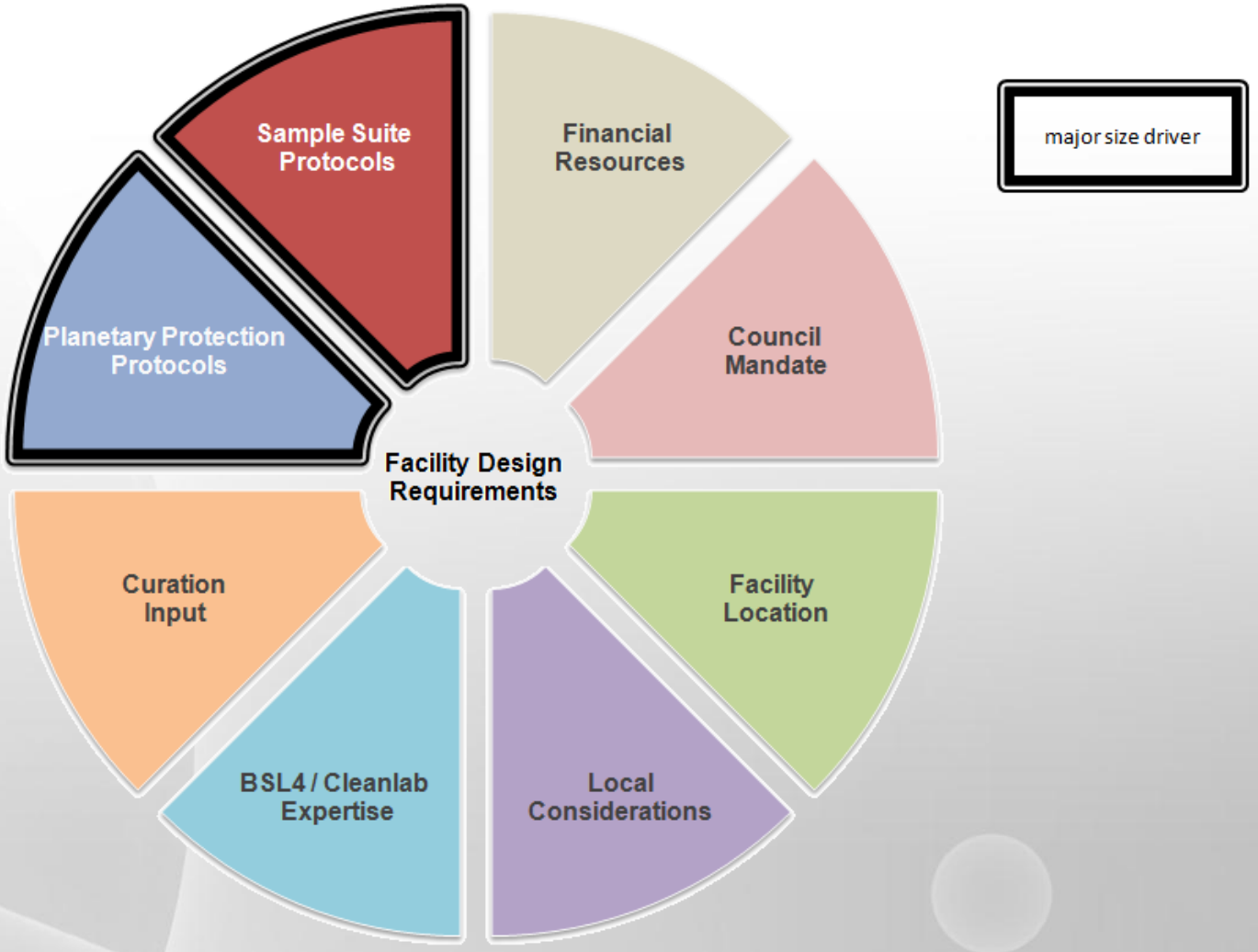


Note: Sample Return Landers (SRL) and Sample Return Orbiter (SRO) can be launched in either order

Notional Campaign Timeline (2033 Sample Return)



SRF Design Considerations



Considerations: Interface with Planetary Protection

- **By defining structure for science oversight, there may be implicit requirements for physical sample management**
  - ie. interface between science desires and planetary protection will need to be carefully managed
    - ❖ *critical issue is to avoid the "stuck in containment" raised by iMARS I*

Facility Needs: SRF

In line with planetary protection baseline, the SRF would:

- contain areas with different biological safety containment levels
- contain areas with different contamination control levels
- have to accommodate the samples returned from Mars and the associated flight hardware (i.e. everything that lands on Earth)

Infrastructure would require capability for:

- capabilities for life detection / biohazard determinations
- preliminary sample examination, including 3D computed tomography
- physical and chemical sample preparation, incl. splitting, cutting, polishing, thermal and liquid extraction and capability for detailed scientific analysis
- sample sterilization (e.g. Cobalt 60 source)

Preliminary Sample Analysis

Initial analysis will follow a pre-designated and peer-reviewed protocol

- this should be our starting place

BSL-4 unlike most others – *no bugs out OR in*

- best model may be forensic science facilities

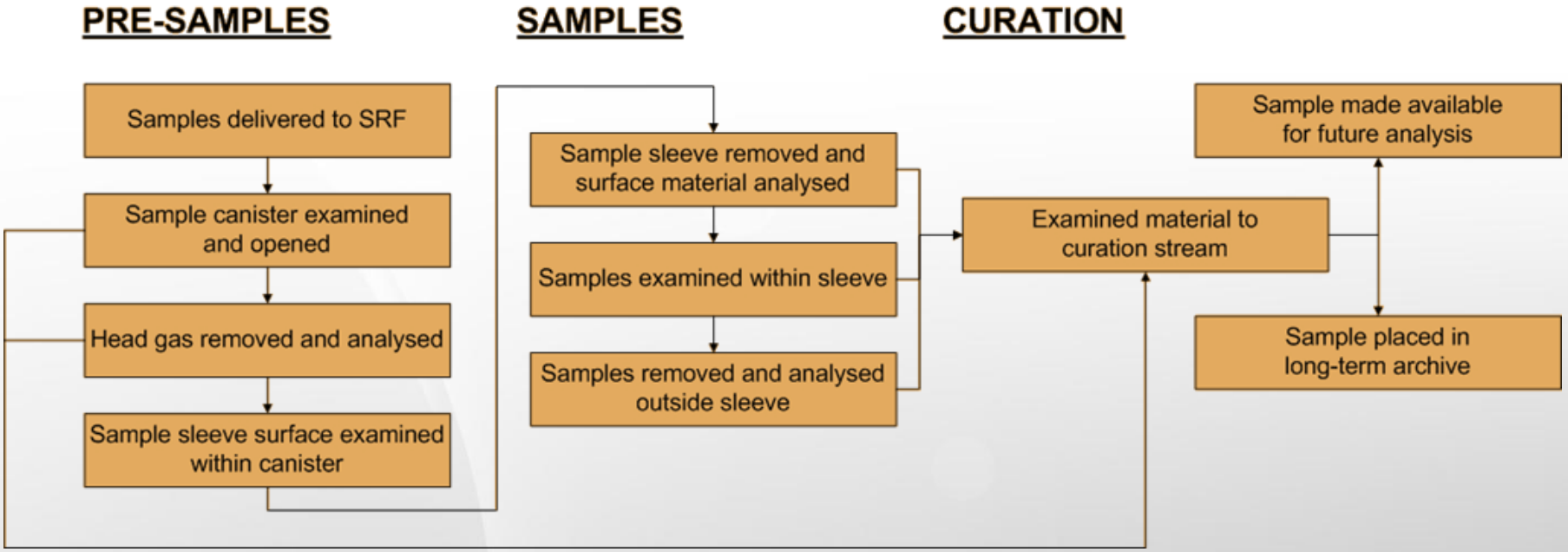
SRF instrumentation chosen ≥2 years in advance limiting ability to carry out state-of-the-art preliminary examination

- adaptability of facility design/infrastructure will be very important

Preliminary analyses carried out in SRF will need to satisfy both Planetary Protection and Science needs

- PP and preliminary science investigations are highly complementary and inform each other

Preliminary Sample Analysis (General Flow)



- Conducted within containment at SRF; initially protocol-dominated
- SRF staff-dominated (MSPET), with some incorporation of Guest / External scientists

Science Access and Allocation

Publish “sampling strategies” protocols ahead of time

- Each “suite” will have to be sub-sampled and allocated differently
- Sample allocation procedures periodically reviewed and updated
- Similar approach developed by IODP → peer-review

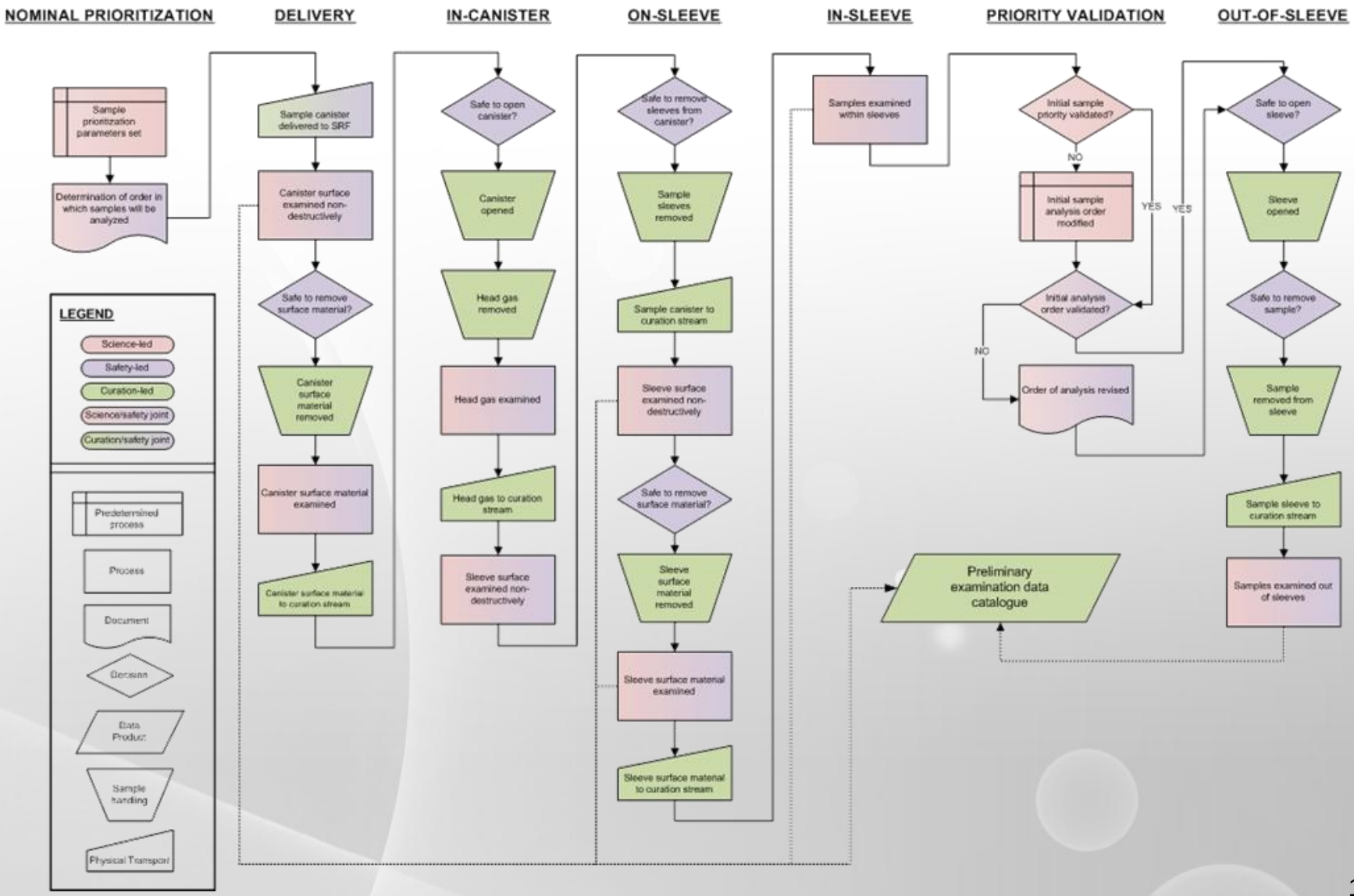
Allocation scenarios have different needs

- Preliminary Examination – including PP investigations
- Ongoing SCF Independent Guest Scientists – independently funded
- Allocation of “contained” samples to outside users
- Allocation of “uncontained” samples to outside users

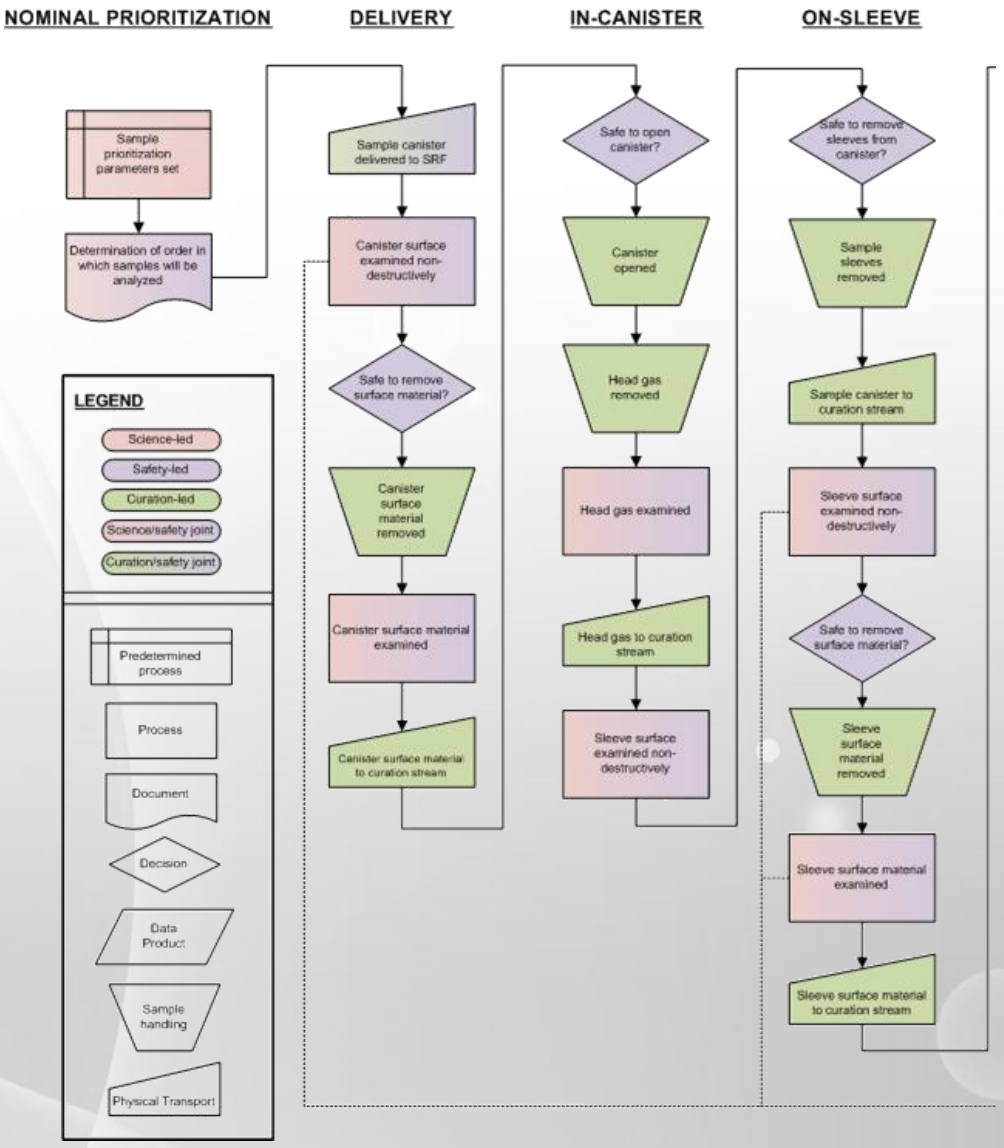
Critical issue is to avoid “stuck in containment” scenario

- Highlighted in iMARS Phase I document – issue of concern to many stakeholders

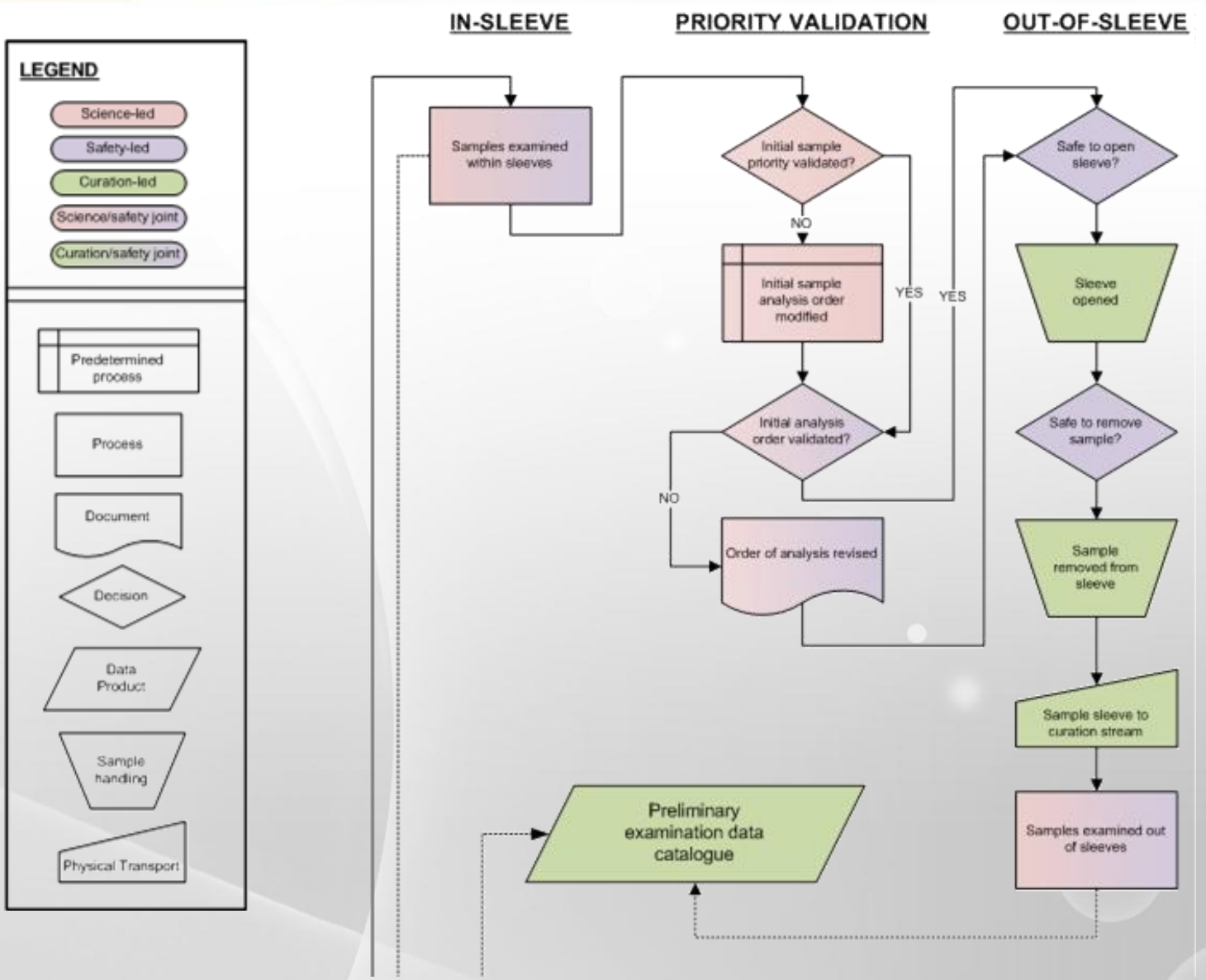
Preliminary Sample Analysis (Detailed Flow)



Preliminary Sample Analysis (Detailed Flow)



Preliminary Sample Analysis (Detailed Flow)



Sample Tracking and Routing

Existing rigorous curatorial protocols and procedures in place for sample tracking and routing e.g. NASA JSC. These should be used as a starting point

- More information needed on how bio-hazardous samples are “curated” in the biosciences

Added complexity of tracking/routing “contained” and “uncontained” samples both within and outside the SRF

- Curation and tracking of “destroyed” or “altered” samples

Curatorial activities carried out by dedicated curatorial staff in the SRF

- Close interaction between SCF Curation, stakeholders, scientific management structure

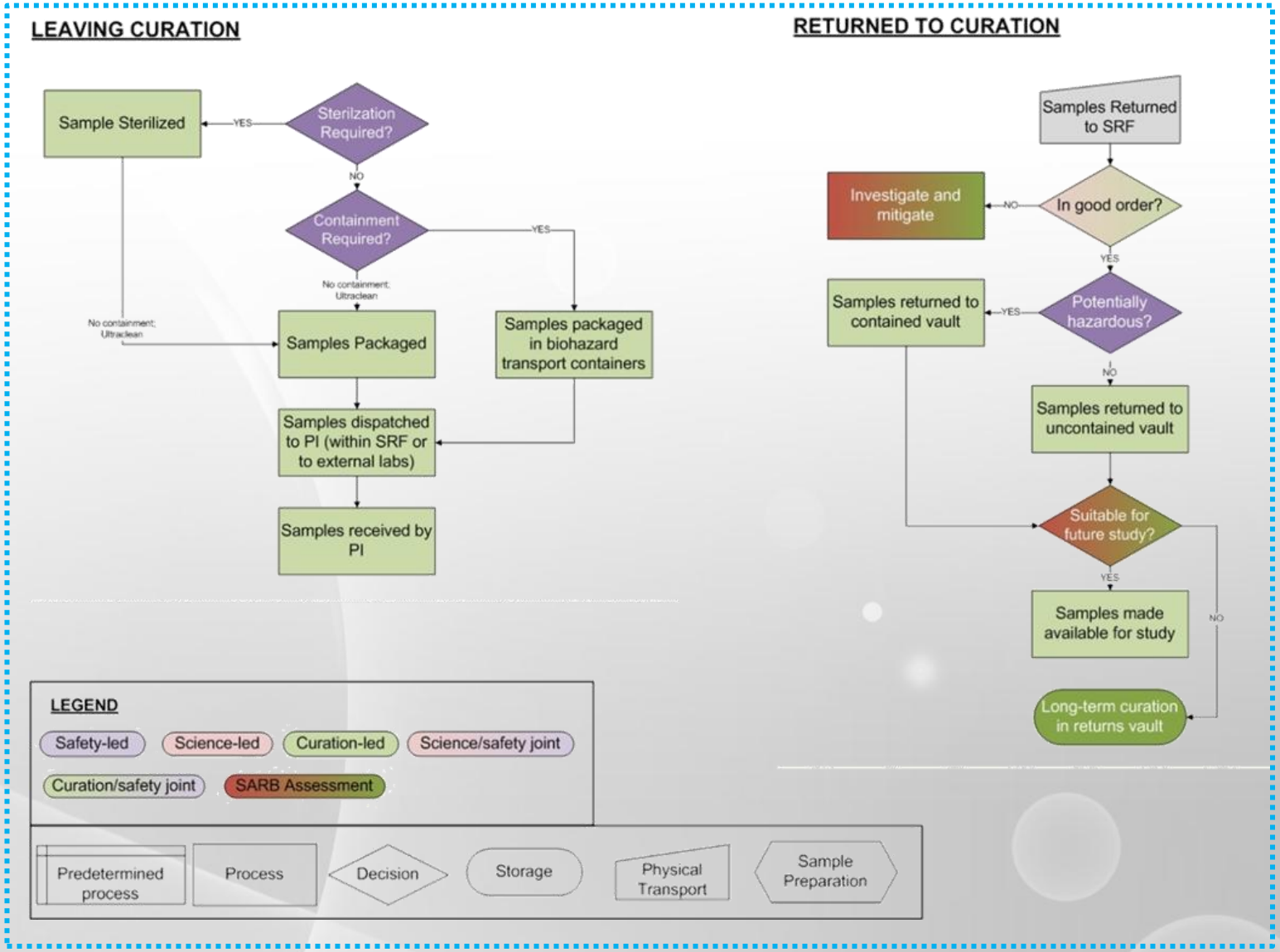
Sample Tracking and Routing

Samples will need to be tracked going OUT of the SRF and coming back IN to the SRF

- Curation and tracking of “destroyed” or “altered” samples
- Avoidance of sample cross-contamination
- “Waste” samples still have scientific value
- Complexity of sub-sample multiplication
  - One sample goes out → TBD number of samples are returned
  - Samples are returned in non-original state, have been studied at different labs etc.
- Ensuring external laboratories maintain sample handling and curatorial protocols e.g. cleanliness, documentation

We have developed a high-level routing protocol for samples going OUT of the SRF and returning IN to the SRF

Sample Routing



Archive/Posterity Samples

iMARS Phase I recommendation of 40 % 'archive' sample remains valid

- Which 40 % is chosen is an open topic
  - 40% of everything?, 40 % of certain samples?
- Archive sampling recommendations will be defined before and during sample acquisition and preliminary investigation
- Should some samples remained unopened ('pristine')?
  - As above → which, how many?
  - 'Blank' samples will be important in this context

Summary

Importance of sample suite definitions on Mars

- Will guide the composition of the in-facility and 'virtual' science teams
- Sampling protocols will affect facility design, curatorial protocols, preliminary examination protocols

Fundamental importance of planetary protection

- Planetary protection protocols influence facility design, guide preliminary examination, determine rate at which samples can be made available to the community

Verification / validation methods

- Verification and validation methods can be investigated and refined now, understanding that revisions will be necessary

Peer review is critical

- … at all areas and stages. Scientific excellence must be the driver

Success relies on international participation

- Will be challenging, but numerous examples of large scale collaborative efforts

The Need for a Planetary Protection Protocol

The iMARS WG strongly recommends that a task group be convened as soon as possible to draft a formal planetary protection protocol for returned martian samples

- Exactly which measurements will be required to fulfil planetary protection requirements?
- What instrumentation will be required to make these measurements?
- Will the probability of finding extant life in Mars samples ever be determined to be low enough to warrant release of unsterilized samples from containment?
- What fraction of a sample should be designated for planetary protection measurements, and will this value change as samples are interrogated?
- To what degree must this fraction be “representative”?
- At what stage will planetary protection measurements be deemed sufficient to accept the risk of losing any possible evidence of life through sterilization?