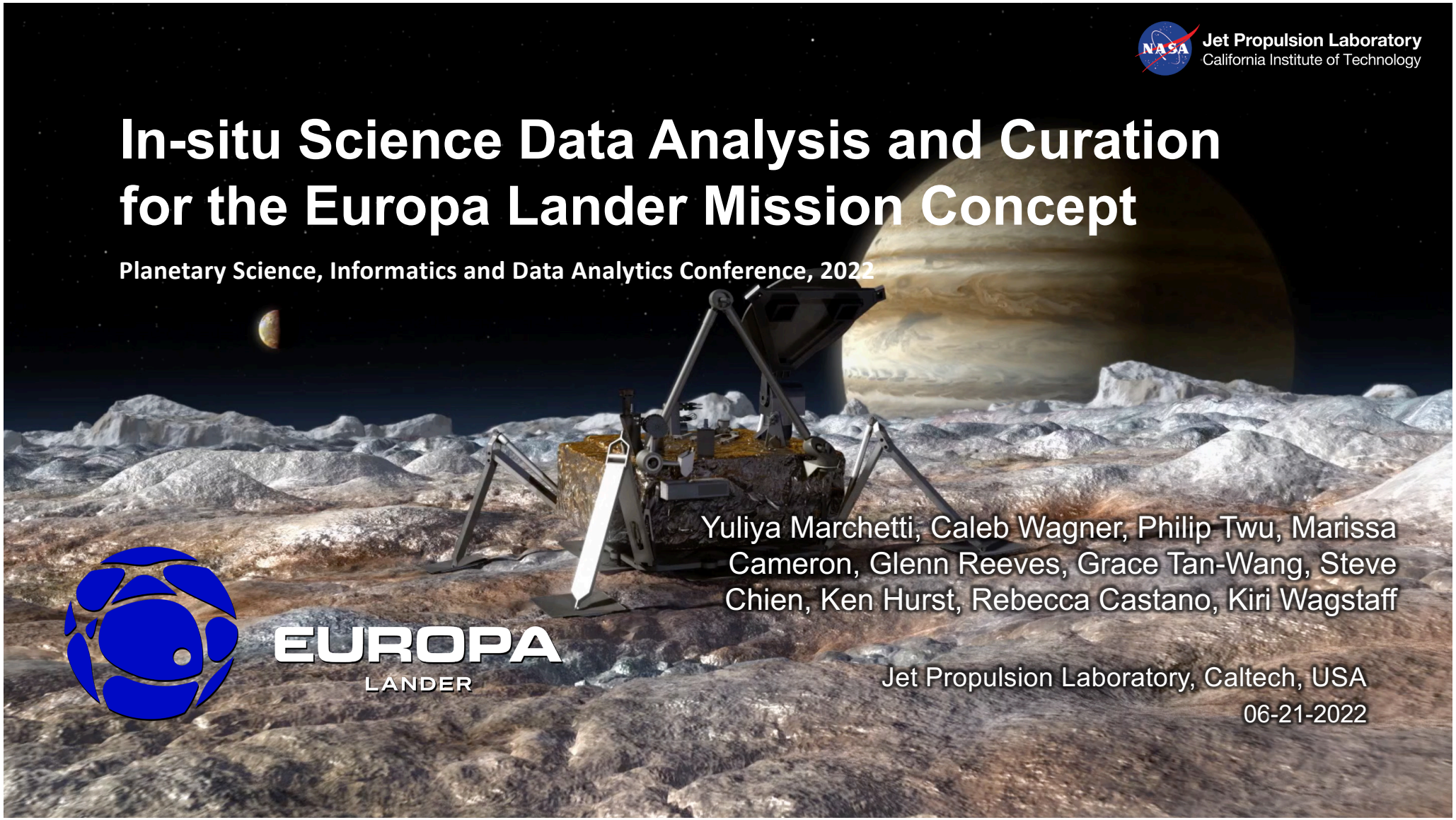
Jet Propulsion Laboratory
California Institute of Technology
In-situ Science Data Analysis and Curation for the Europa Lander Mission Concept
Planetary Science, Informatics and Data Analytics Conference, 2022
Yuliya Marchetti, Caleb Wagner, Philip Twu, Marissa Cameron, Glenn Reeves, Grace Tan-Wang, Steve Chien, Ken Hurst, Rebecca Castano, Kiri Wagstaff
EUROPA
LANDER
Jet Propulsion Laboratory, Caltech, USA
06-21-2022

# Outline


- Europa Lander Mission Concept
- Motivation for Autonomy and Onboard Data Analysis
- Mission Concept Prototype

- Onboard Data Analysis Framework:
  - Synthetic Data and Instruments
  - Science Value Assessment
  - Content-based Data Reduction

- Results
- Summary and Future Work

# Europa Lander Mission Concept

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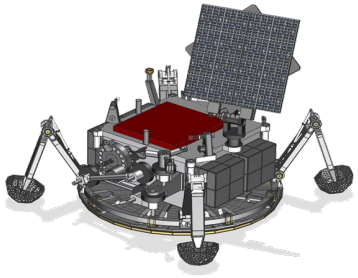
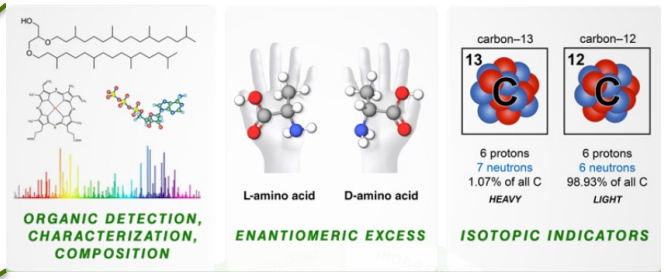
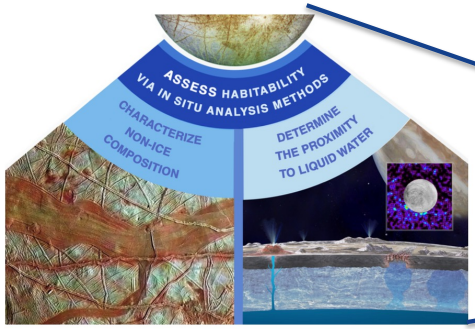
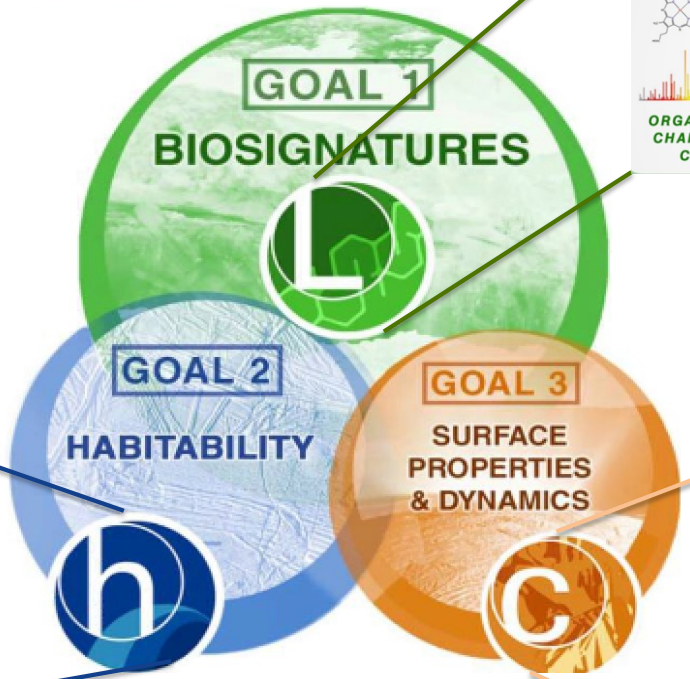


- Search for evidence of biosignatures on Europa

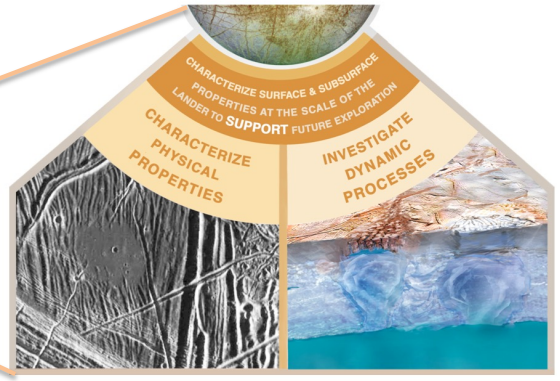



- Asses the habitability of Europa via in situ measurements.




- Characterize the surface and subsurface of Europa.



# Motivation

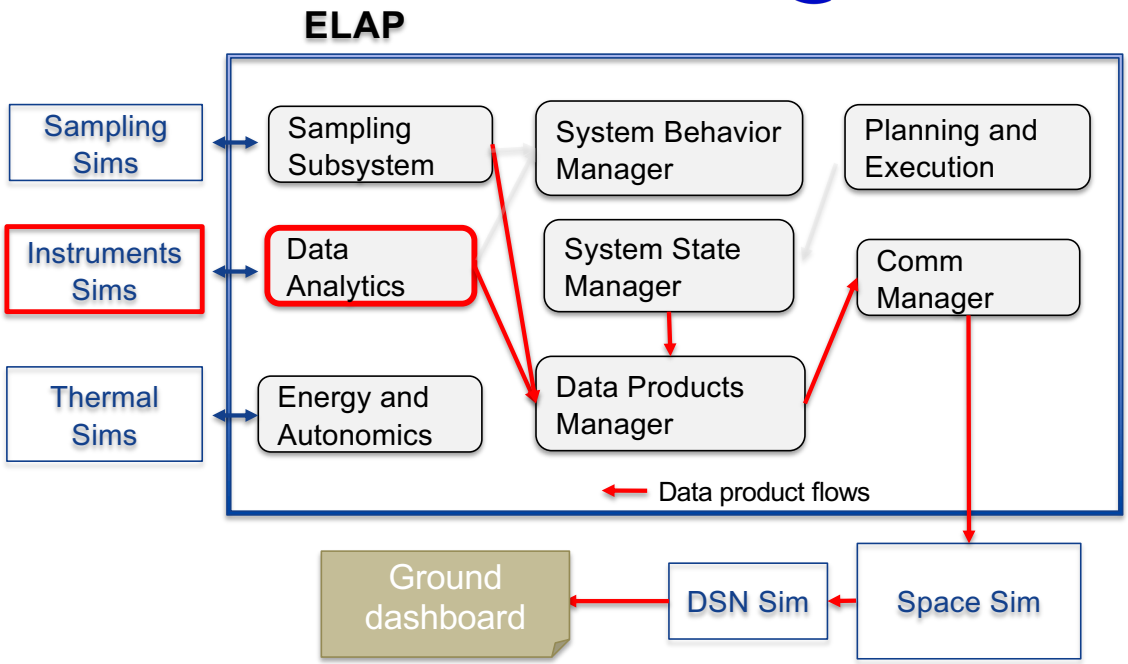

**Landed missions on ocean worlds are challenging!**

- Extremely short mission durations:
  - Days to months nominal life
  - Limited energy
  - Radiation
- Extremely limited communication bandwidth:
  - 42 hour blackout/comm periods
  - Tiny downlink budgets
- Unknown and unexpected terrain, surface and conditions

- ❑ Increased need for an **autonomous system.**
- ❑ **Science-driven** onboard data analysis and curation that informs the autonomy**.**
- ❑ Science data yield optimization through **content-based data reduction.**

# Europa Lander Autonomy Prototype

- Rapid scenario experimentation to investigate various technologies and architectures for a landed Europa mission concept.
- Incorporates and establishes principles of autonomous operations to address challenges of a landed mission:
  - System level: planning and execution
  - Functional level: sampling and analytics




**ELAP fully integrates onboard data analysis and curation framework.**

# ELAP Science Data Analytics

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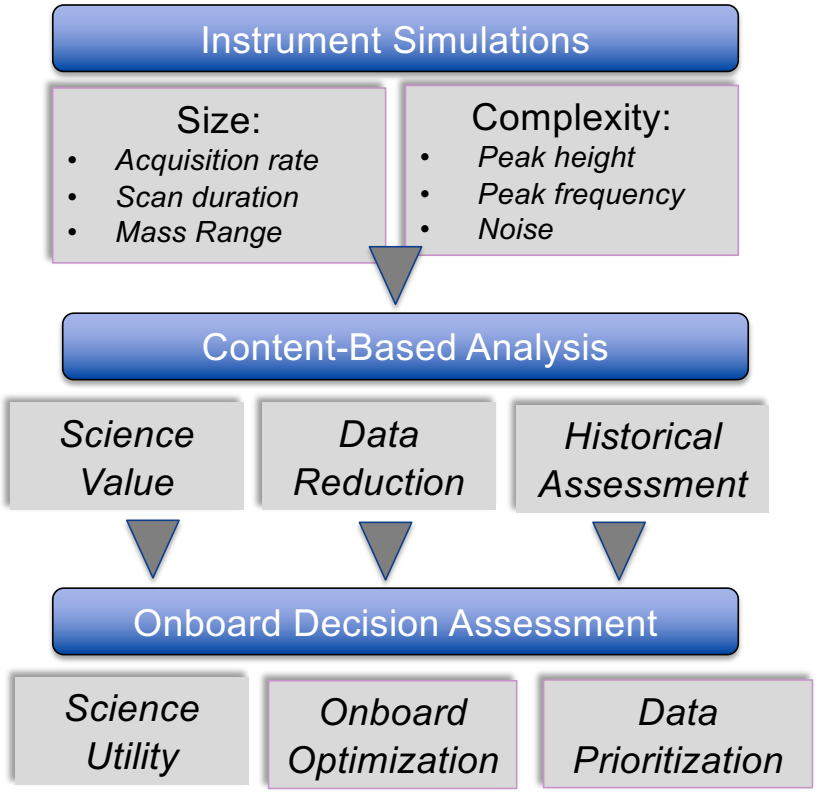
- **Emulate** datasets from generic instruments.
- Science value assessment:
  - **Identify** data of highest science value through content-based analysis, e.g. detection algorithms.
- Content-based data reduction:
  - **Reduce** and summarize data based on the science value and return the most salient information.
- **Optimize** the science value, data size and the energy trade-offs to reduce risks and increase yield (Planning & Execution).



# Realistic Instrument Simulations

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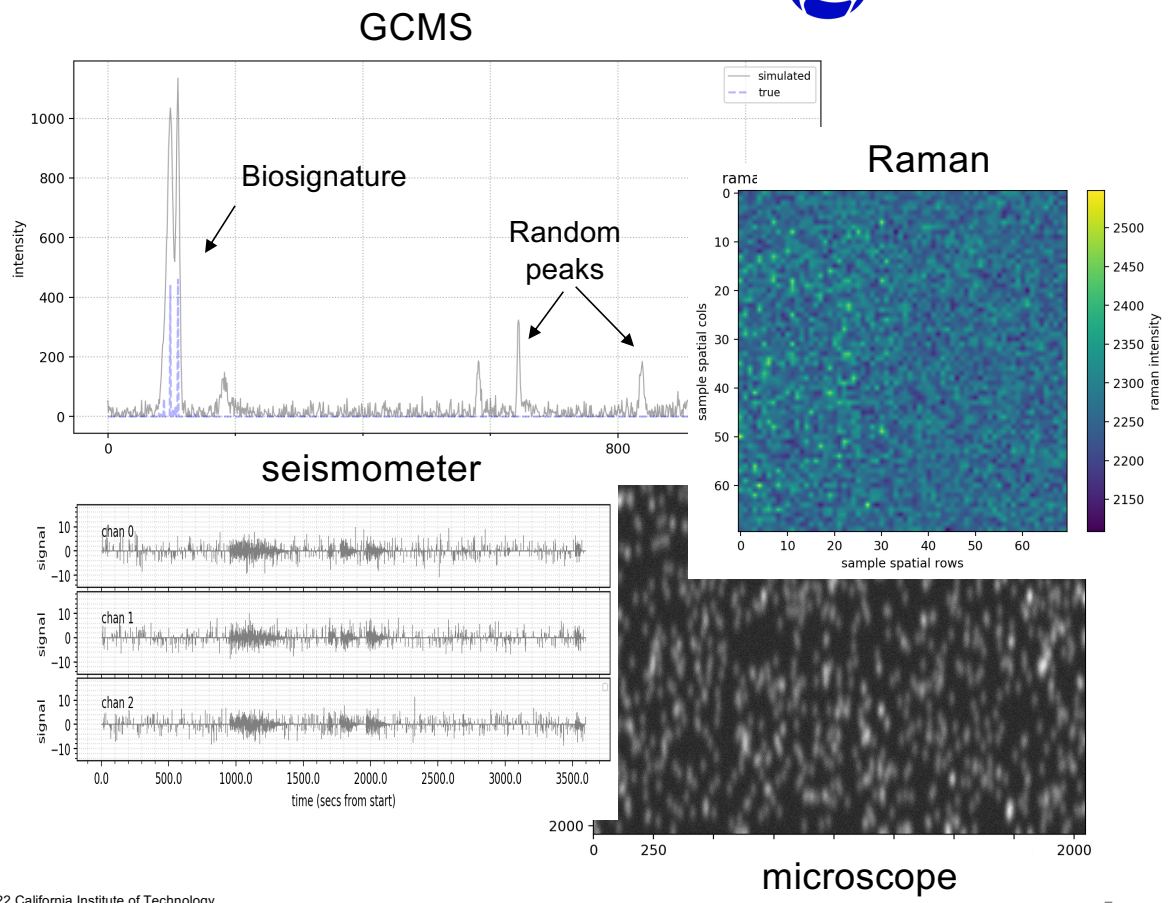
- Sampling instruments, triggered by each sample: *GCMS, Raman, Microscope*
- Streaming or episodic instruments, generated continuously or on demand for a time period: *Seismometer, Science camera*

Europa Lander 2016 science report recommends a suite of generic instruments to extract the best possible scientific evidence of life.

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# Science Value Assessments

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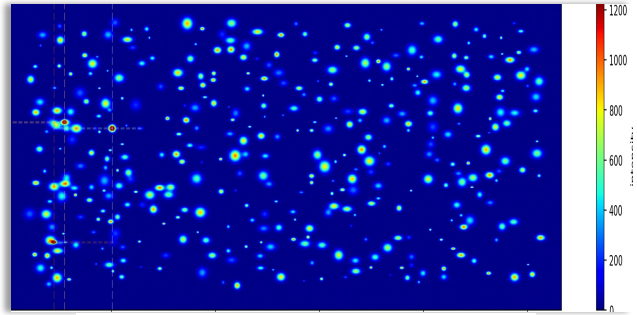
Science value is a predetermined "objective" *measure* that compressed a science goal into a quantitative value and is one of the key aspects to inform autonomy decisions.

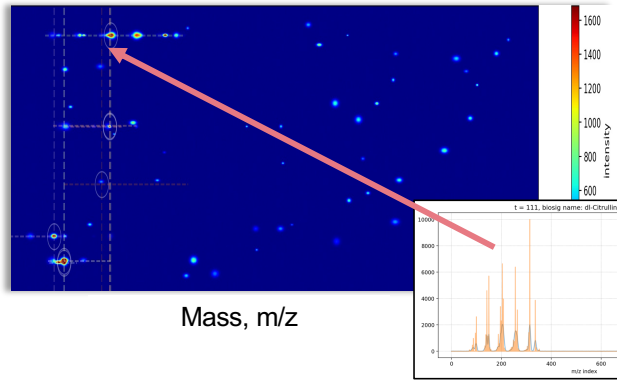
- GCMS represents spectral peaks and intensities:
  - Abundance - presence of peaks and the area under them as vs the background noise: *normalized clustering entropy*
  - Patterns - similarity of spectral profiles to a library of known biosignatures: *cosine similarity*

Abundance: high, 0.89



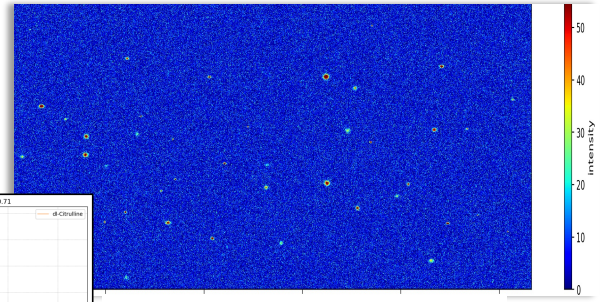

Mass, m/z

Patterns: high, 0.78




Mass, m/z

Abundance: low, 0.1




Mass, m/z

# Content-based Data Reduction

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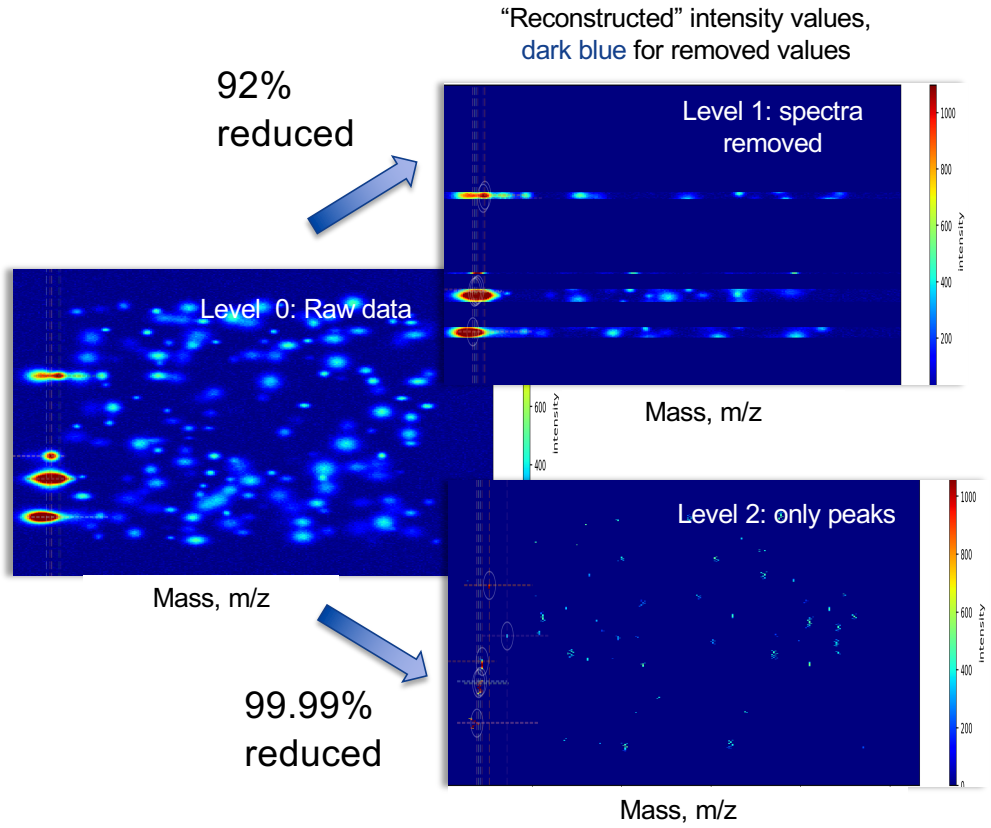
- **Content-dependent** analysis + reduction:
  - Depends on science value (and data)
  - The resulting data size is not known a priori
  - Depends highly on the implemented methodology and assumptions
- Prototype reduction methods:
  - Subset level - Only interesting parts of the dataset are returned with noise removed:
    - Remove “uninteresting” spectra
  - Summarized level - Summary statistics are returned:
    - Return peak intensities and their locations
  - *Reduced science value* based on estimated *normalized mutual information loss*



# Experimentation and Results

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- A set of science goals for multiple instruments, "*science bingo*":
  - GCMS: abundance, patterns, isotopes, chirality
  - Raman: biomineral similarity
  - Microscope: cell-like structures, properties

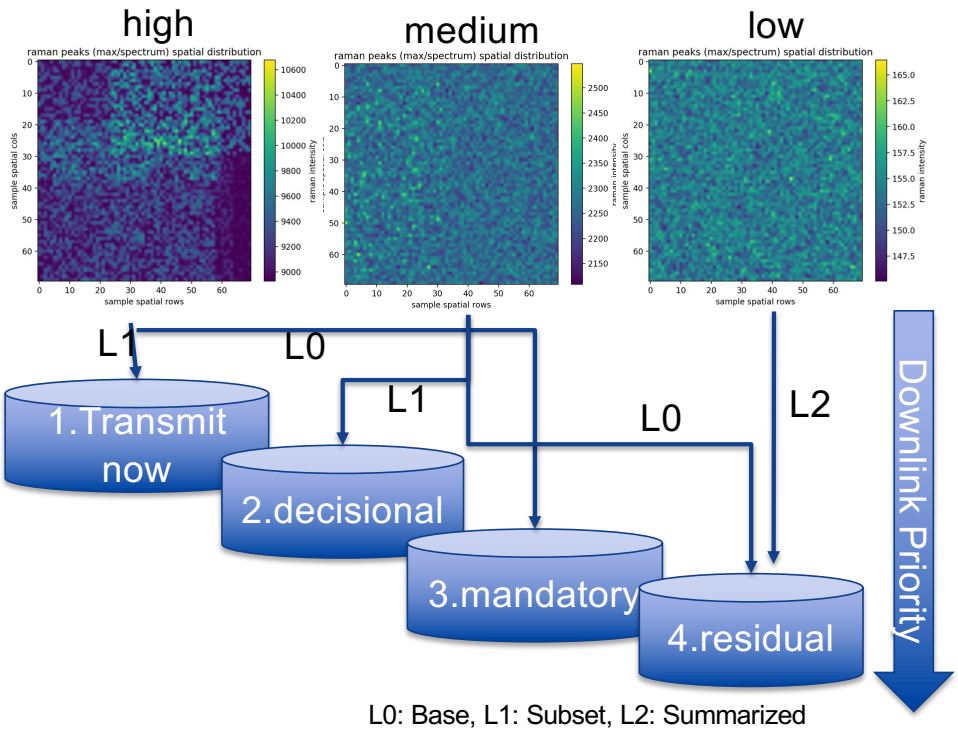
- Low, high and medium scenarios to test various data reduction levels:

**Size and science value reductions for a set of sampling instruments:**

| | | Subset | | | Summarized | | |
|---|---|---|---|---|---|---|---|
| | Raw | Size | % | *SV % | Size | % | *SV % |
| High | 62MB | 43MB | 0.69 | 0.72 | 1MB | 0.02 | 0.06 |
| Medium | 62MB | 9.5MB | 0.15 | 0.38 | 0.08MB | 0.001 | 0.02 |
| Low | 62MB | 2.4MB | 0.04 | 0.11 | 0.01MB | 0.000 | 0.009 |

*SV % = Science value % preserved in reduced data

- Downlink prioritization, planning and execution for science return:




L0: Base, L1: Subset, L2: Summarized

# Summary and Future Work

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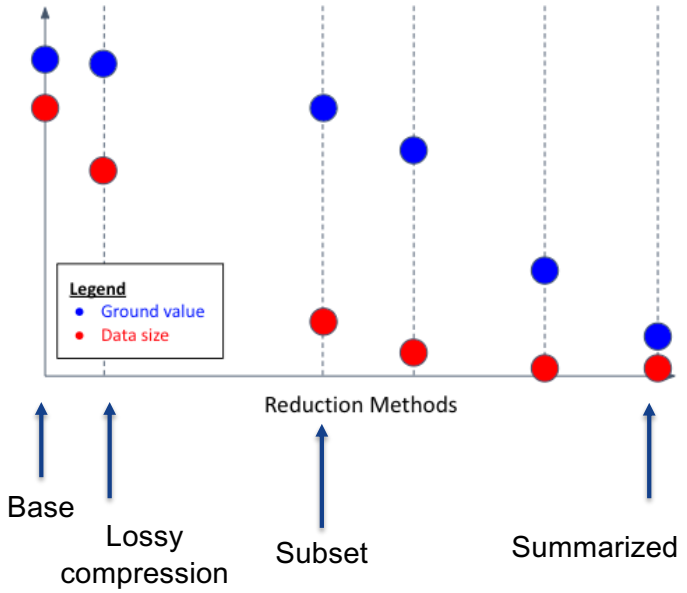
- The first full integrated software prototype that includes realistic science data autonomous assessments and curation:
  - Allows experimentation
  - Instruments joint representation
  - Autonomy feedback
- Retrospective data assessment, long-term trends, conditional and jointly estimated science values
- Abundance of methods can be implemented for science value estimation and data reduction:
  - Adaptive autonomous selection of data reduction
- Close collaborations with science and instrument teams!!




Content-based data reduction can provide significantly larger data volume reduction, while ensuring that the most critical data reaches the scientists.

# Thank you!

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