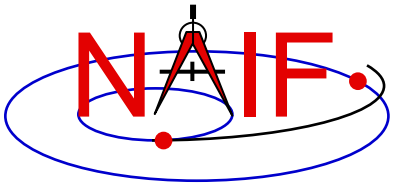
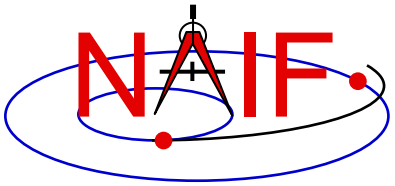


Navigation and Ancillary Information Facility

The SPICE Story

April 2023



Why Did NAIF Build SPICE?

Navigation and Ancillary Information Facility

- **Starting in the early 1980's scientists said they would like to:**
  - **use common observation geometry computation tools and methods throughout a project's lifecycle, and for all projects (national and international)**
  - **be able to produce custom observation geometry calculations themselves, whenever and however they want**
  - **understand the calculations and data used to produce observation geometry data**
  - **have the ability to revise the data and software tools used to produce their own observation geometry data**

What Existed Prior to SPICE ?

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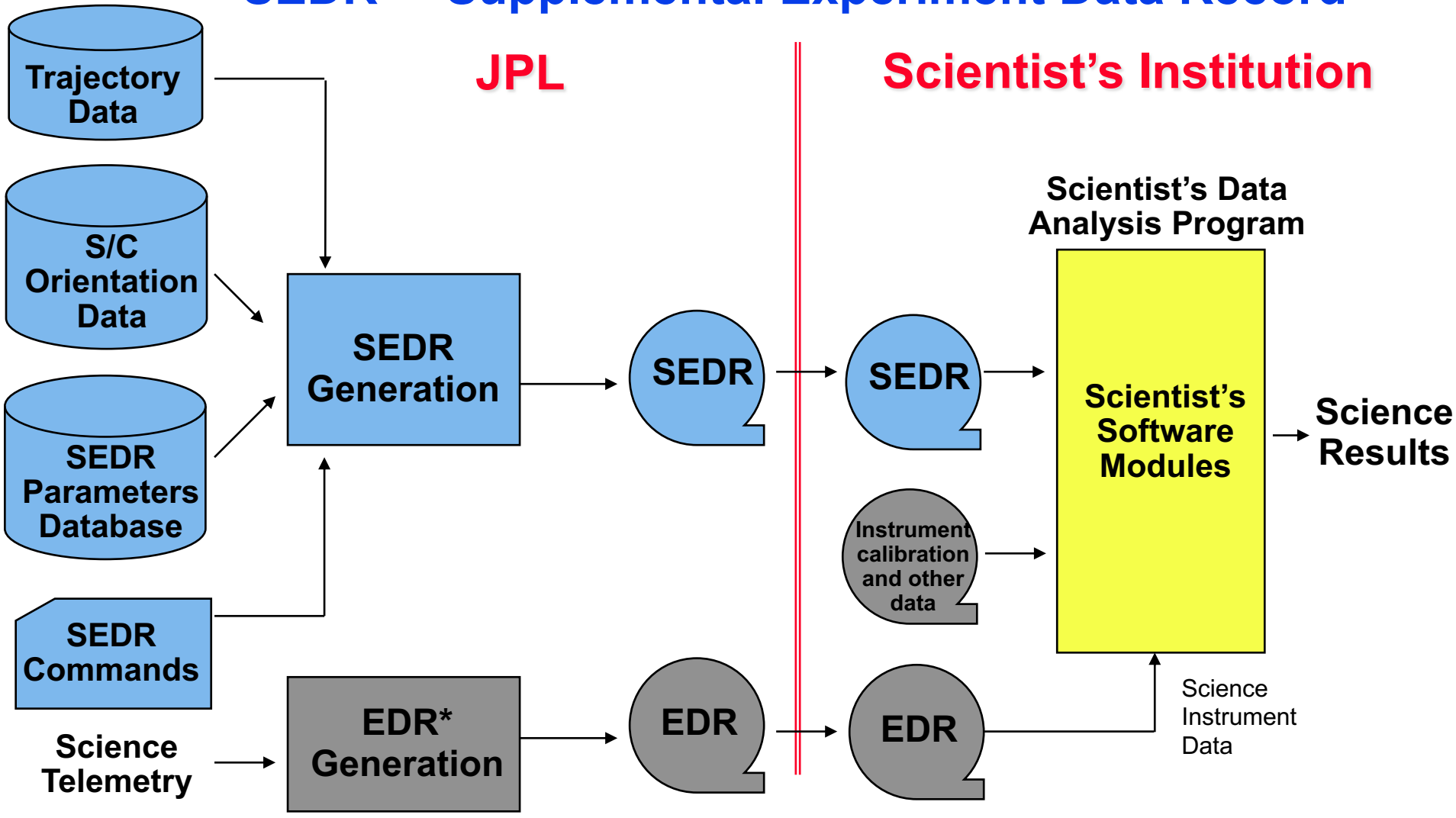
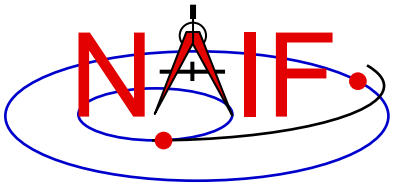
"SEDR" - Supplemental Experiment Data Record



* EDR = Experiment Data Record = "raw" science instrument data



SEDR System Characteristics

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- **The SEDR generation program was built and operated at JPL**
  - **Scientist's requirements on SEDR had to be provided long before launch**
    - » **Late or post-launch updates were hard/expensive to accommodate**
      - **Difficult to change WHAT gets computed**
      - **Difficult to change HOW items are computed (algorithms, parameters)**
      - **Difficult to change the TIMES at which items get computed**
  - **Generally only one SEDR file would be produced for each period of time**
    - » **Result: the scientist can't get better observation geometry data if/when better inputs (e.g. spacecraft trajectory or orientation, etc.) become available**
  - **SEDR generation was done "in the blind"**
    - » **Operators were not familiar with processes used to make the inputs**
    - » **Operators were not familiar with scientist's processing schemes**
    - » **Result: SEDR often did not fully meet science team's expectations**
  - **The SEDR system was not exportable to other institutions**

The SPICE Idea

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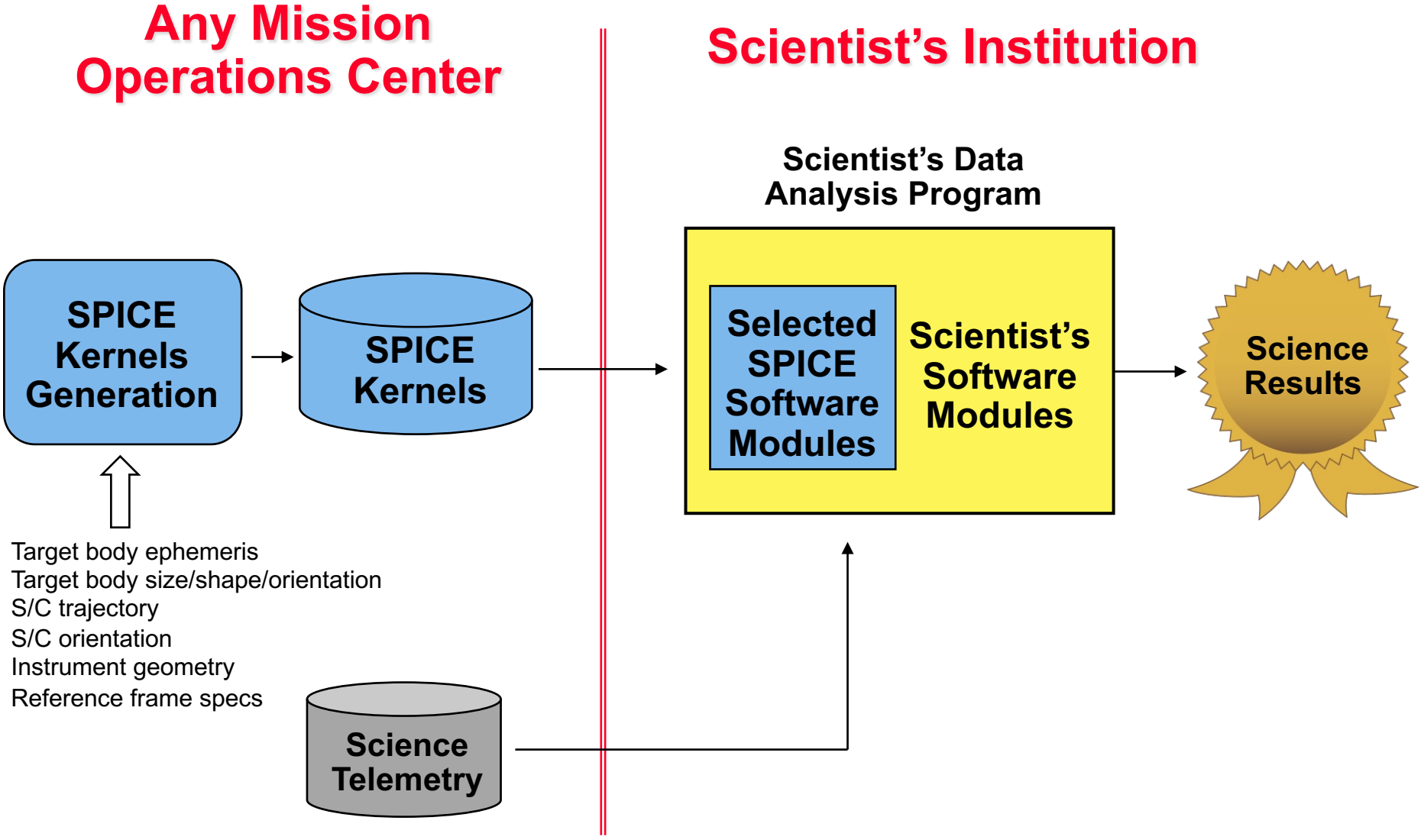
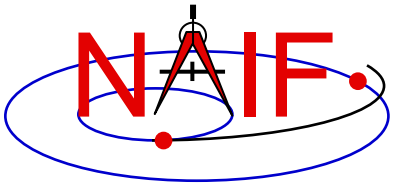


SPICE Benefits vs. SEDR

- **The customer has great flexibility in deciding:**
  - what observation geometry parameters are computed
  - at what times or at what frequency these parameters are computed
  - for what time span(s) these parameters are computed
  - electing if/when to re-do parameter computations using new (better) or otherwise different data as inputs
- **The customer also has:**
  - multi-mission tools and methods that can be reused on many tasks
  - full visibility into algorithms and data used in geometry calculations
- **The flight project operations center can:**
  - concentrate on producing better ancillary data, rather than on producing lots of SEDRs and frequently updating the SEDR software
- **The SPICE process may be replicated anywhere**

SPICE "Challenges" vs. SEDR

- There are often many SPICE data files produced by the mission
  - It can be a challenge to select the correct ones for a particular job
- Customers (usually) must do some non-trivial programming to read SPICE data and compute whatever is needed
- If the mission operations center is other than JPL, the appropriate project people need to learn how to produce and validate their SPICE data
- In some areas of SPICE, the offering of choices to allow correct handling of different situations may present complexity that is unwarranted for "simple" problems

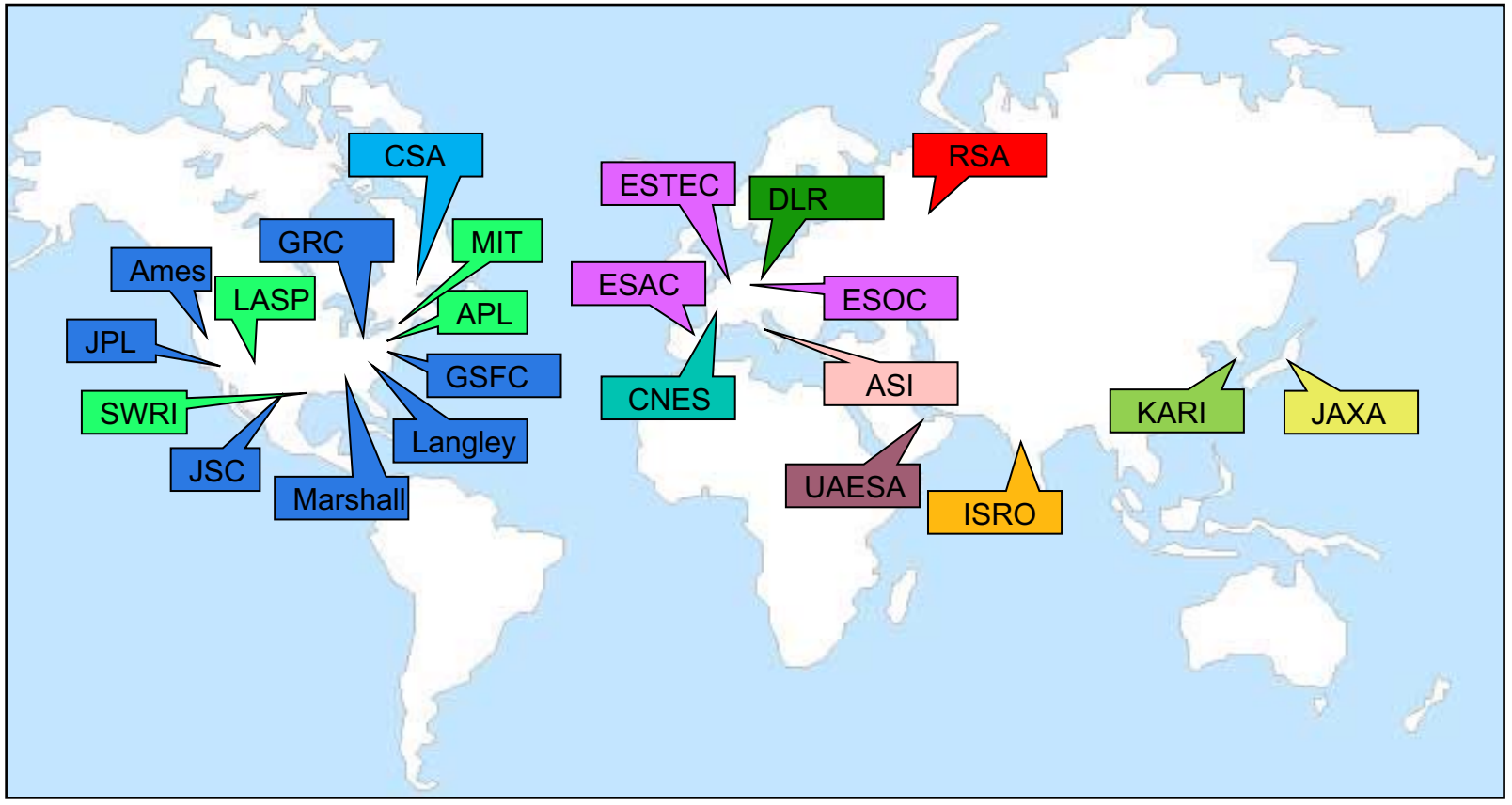


SPICE Evolution

- **At the behest of scientists, over many years the use of SPICE has grown throughout NASA and within space agencies and countries around the globe**

Space Agencies Using SPICE

Navigation and Ancillary Information Facility



- NASA Field Centers
- U.S. Institutions
- Canadian Space Agency
- UAE Space Agency
- European Space Agency
- French Space Agency
- German Space Agency
- Italian Space Agency
- Indian Space Research Organization
- Japan Aerospace Exploration Agency
- Russian Federal Space Agency
- Korean Aerospace Research Institute

SPICE Flight Project Users

Navigation and Ancillary Information Facility

Data Restorations	Selected Past Users	Current Users	
Apollo 15, 16 [L]	Magellan [L]	Mars Odyssey	Parker Solar Probe
Mariner 2 [L]	Clementine (NRL)	Mars Reconnaissance Orbiter	Hubble Space Telescope [S][L]
Mariner 6 [L]	Mars Pathfinder	Mars Science Laboratory	James Webb Space Telescope [S][L]
Mariner 7 [L]	NEAR	Juno	Lunar Gateway
Mariner 9 [L]	Deep Space 1	MAVEN	Dragonfly
Mariner 10 [L]	Galileo	SMAP (Earth Science)	IMAP
Viking Orbiters [L]	Genesis	OSIRIS REx	MAIA
Viking Landers [L]	Deep Impact	InSight	NEO Surveyor
Pioneer 10/11/12 [L]	Stardust/NExT	Mars 2020	NEOWISE
Haley armada [L]	Mars Global Surveyor	Europa Clipper	SPHEREx
Phobos 2 [L] (RSA)	Phoenix	NISAR (NASA and ISRO)	SunRISE
Ulysses [L]	EPOXI	Psyche	TESS
Voyagers [L]	GRAIL	Lucy	LunaH-Map (Arizona State)
Lunar Orbiter [L]	DAWN	Janus	Lunar IceCube (Moorehead State)
Helios 1,2 [L]	Cassini Orbiter	Lunar Flashlight	GOLD (LASP, UCF) (Earth Science) [L]
Huygens Probe (ESA) [L]	Mars Exploration Rover	VERITAS	Emmirates Mars Mission (UAE via LASP)
	Mars Express (ESA)	DAVINCI+	Armadillo (CubeSat, by UT)
	Venus Express (ESA)	JUICE (ESA)	ExoMars RSP (ESA, RSA)
	Rosetta (ESA)	Bepicolombo (ESA, JAXA)	Proba-3 (ESA)
	Mars 96 (RSA)	Korean Pathfinder Lunar Orbiter (KARI)	Solar Orbiter (ESA)
	Phobos Sample Return (RSA)	ExoMars 2016 (ESA, RSA)	Hera (ESA)
	Messenger	Akatsuki (JAXA)	EnVision (ESA)
	Chandrayaan-1 (ISRO)	New Horizons	Gaia (ESA)
	Hayabusa (JAXA)	Deep Space Network	INTEGRAL (ESA)
	Kaguya (JAXA)	Voyager	GEO satellites (EUMETSAT) [L]
	LCROSS	Lunar Reconnaissance Orbiter	MMX (JAXA)
	LADEE	Hayabusa-2 (JAXA)	SLIM (JAXA)
	Spitzer Space Telescope	DART	Aditya-L1 (ISRO)
	STEREO	NEA Scout	MOM (ISRO)
	Kepler	VIPER	Chandrayan-2 (ISRO)
[L] = limited use	ISO [S] (ESA)		Altius (Belgian earth science satellite)
[S] = special services	Smart-1 (ESA)		Spectrum-RG (RSA)

NAIF had, has, or will have project-supplied funding to support mission operations, consultation for flight team members, and SPICE data archive preparation.

NAIF had, has, or will have NASA funding to support a foreign partner in SPICE deployment and archive review, and to consult with flight team SPICE users.

NAIF had, has, or will have token funding to consult with kernel producers.

NAIF had or has PDS authorization and funding to consult on assembly of a SPICE PDS archive.

NAIF had performed data restoration under PDS funding.

Missions that used, use, or will be using SPICE without any help from NAIF.