PACE Mission Systems Engineering for UMBC

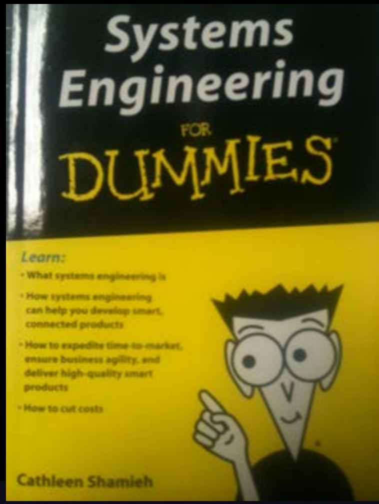
Gary Davis

Aug 2022

(Plankton, Aerosol, Cloud, ocean Ecosystem)

PLOT SPOILERS:

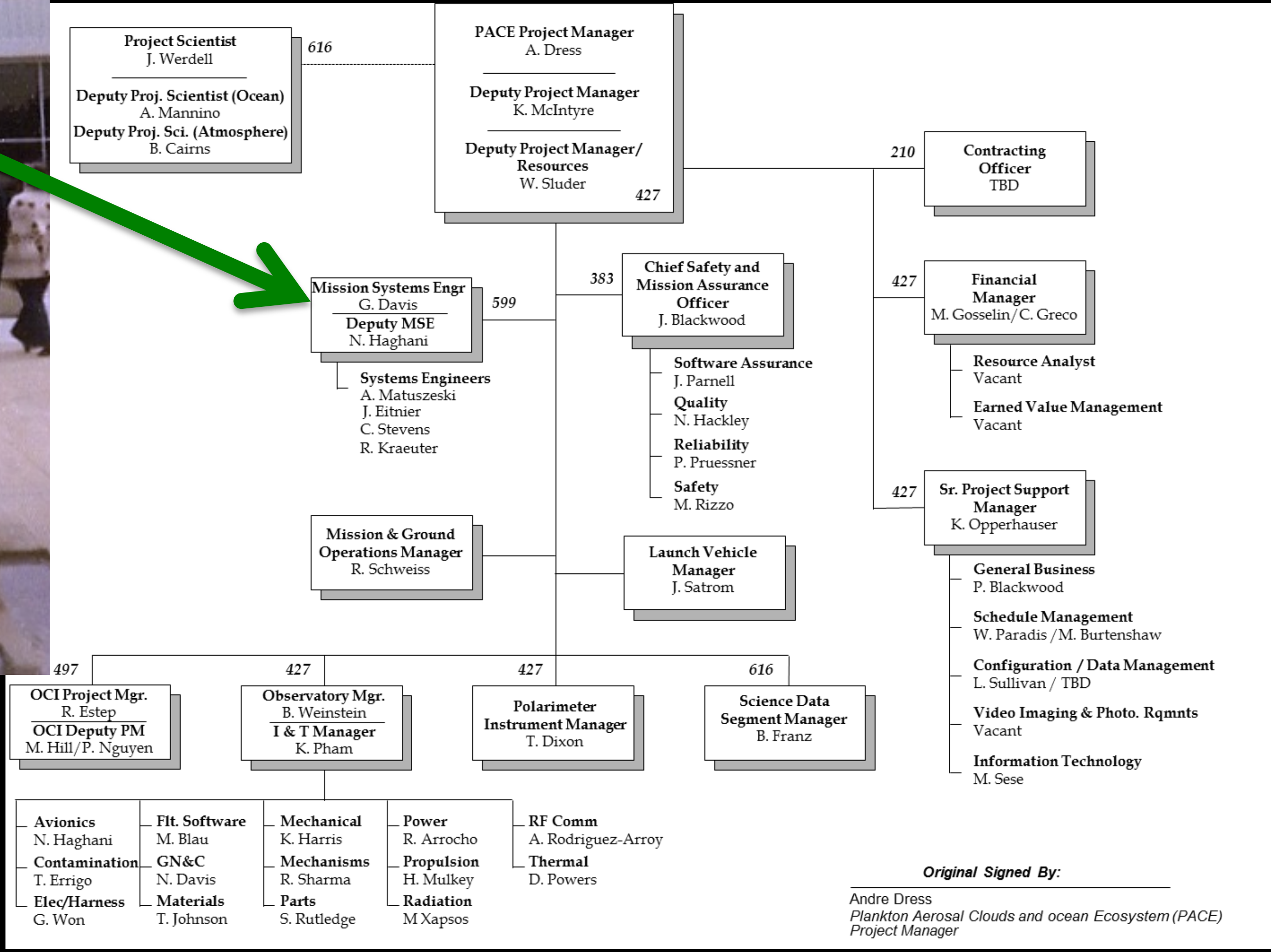
- Who am I and how did I get here?
- Stories & Tall Tales: Motherhood & Apple Pie ->
- Launch Video!!
- Take credit for others' great work
- Time for questions at the end, but it's OK to interrupt and ask questions at any time!



HARP NASA OCI SPEX

No ITAR Material

Bios: Who was I before PACE?



Wind
RHESSI
Voyager
Stereo
QuikSCAT
ACRIMSAT
ERBS
EO-1
DMS
TRMM
ICESat-2
SOHO
Geotail
THEMIS
Aqua
Landsat 7
TOPEX
CALIPSO
TRACE
TIMED
Terra
GRACE
ACE
SORCE
Cluster
SDO
Aura
AIM
PIES
IMAGE
FAST
GPM
PACE
GOES
Polar
GAS/
SPARTAN
MMS
Triana/
DSCOVR
Solar-B
NPP
Aquarius
IBEX
TDRSS
LDCM
CloudSat
RBSP
Osiris-Rex
(Sample Return)
TWINS
(Instrument)
Cassini
WMAP
NuSTAR
JWST
HST
WISE
GALEX
New Horizons
Messenger
Spitzer
SWAS
Astro-H
Galileo
Juno
IUE
RXTE
MAVEN
Integral
Pioneer
EUVE
FUSE
Swift
COBE
Mars Science
Laboratory
Fermi
Compton
GRO
LADEE
LRO

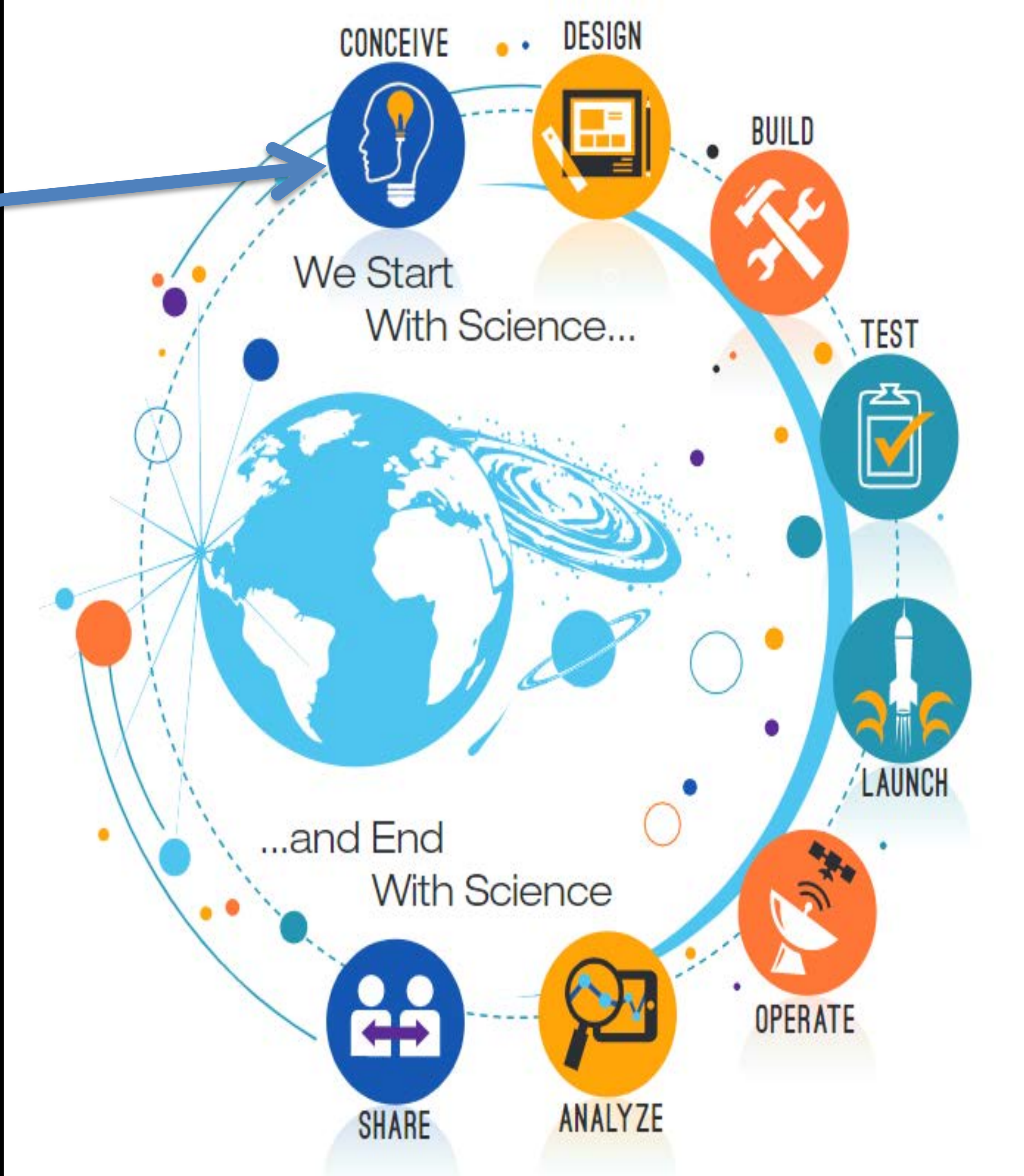
PACE Mission Systems:
What do we do?

Zany Scientists' Ideas

"Proposal Phase"

Pre-Phase-A

Technology Studies




THE GOOD
THE BAD
AND THE UGLY

Conceiving a Space Mission

- Things to be aware of:
- Cost to get to orbit is very high…

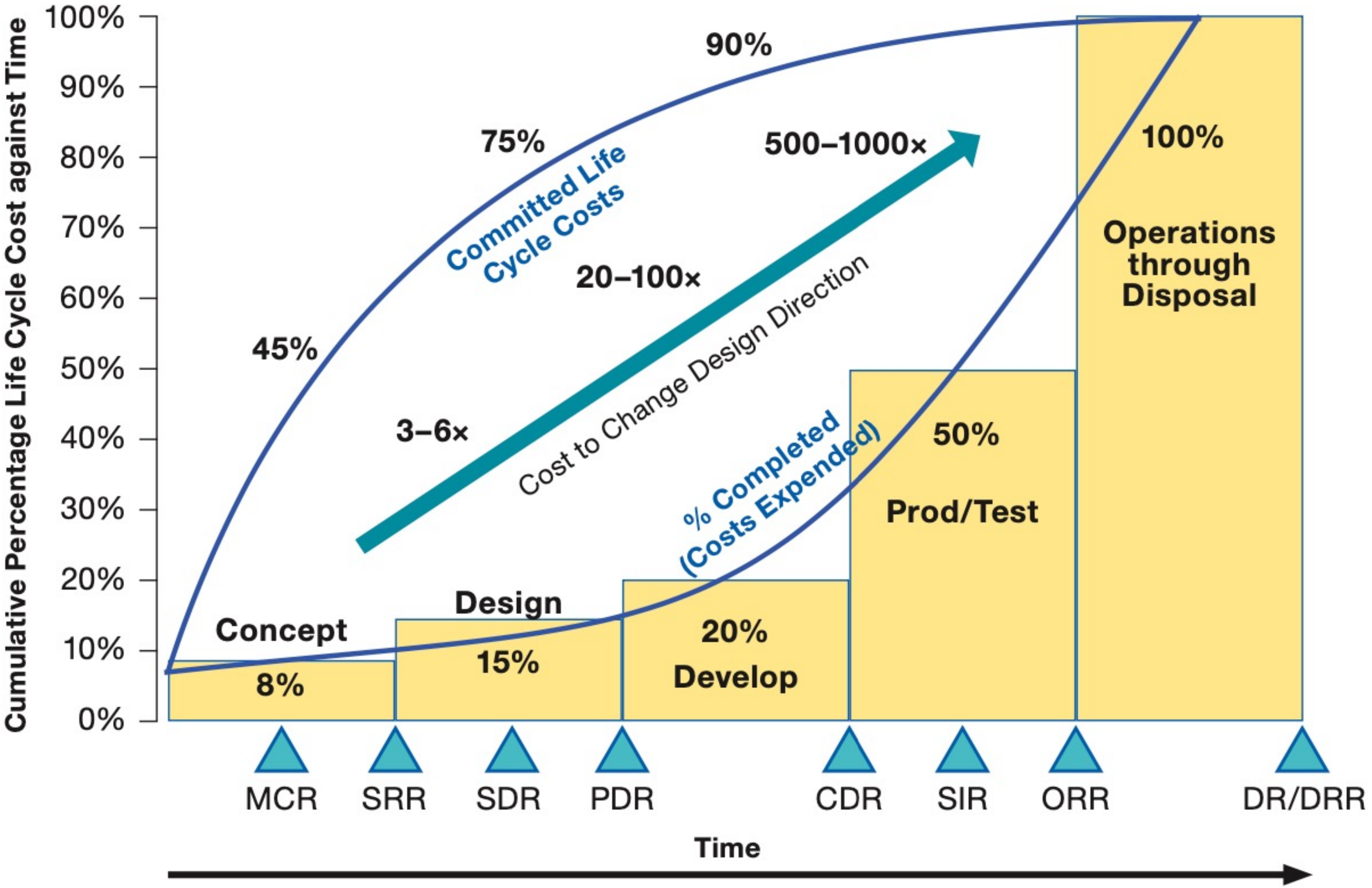
  …This makes reliability important . . .

  . . . Which drives cost.
- Cost and schedule management & realism are important.
- Simplicity & robustness are best done from the beginning and not “tacked on” at the end. Δcost for Δchange increases with time!
- Launch Vehicles are good, but not perfect.

- Questions to ask:
- What data do I need? [-> drives instrument design]
  - Survey? Targets? Ephemeral?
  - Wavelength(s)? [-> drives detector technology]
  - Resolution? [-> drives optics]
- One spacecraft, or constellation?
- Orbit selection? [-> drives launch vehicle]
- Who gets data? How fast? [-> drives ground system]
- Which group(s) are doing the above?
  - Have they done it before?
- What technology needs to be developed?
  - Is there sufficient time/$?
  - If not, backups or fallback plan?

Space Missions are Costly, Risky, and take a long time. Do you really NEED to go to space?

From NASA SE Handbook

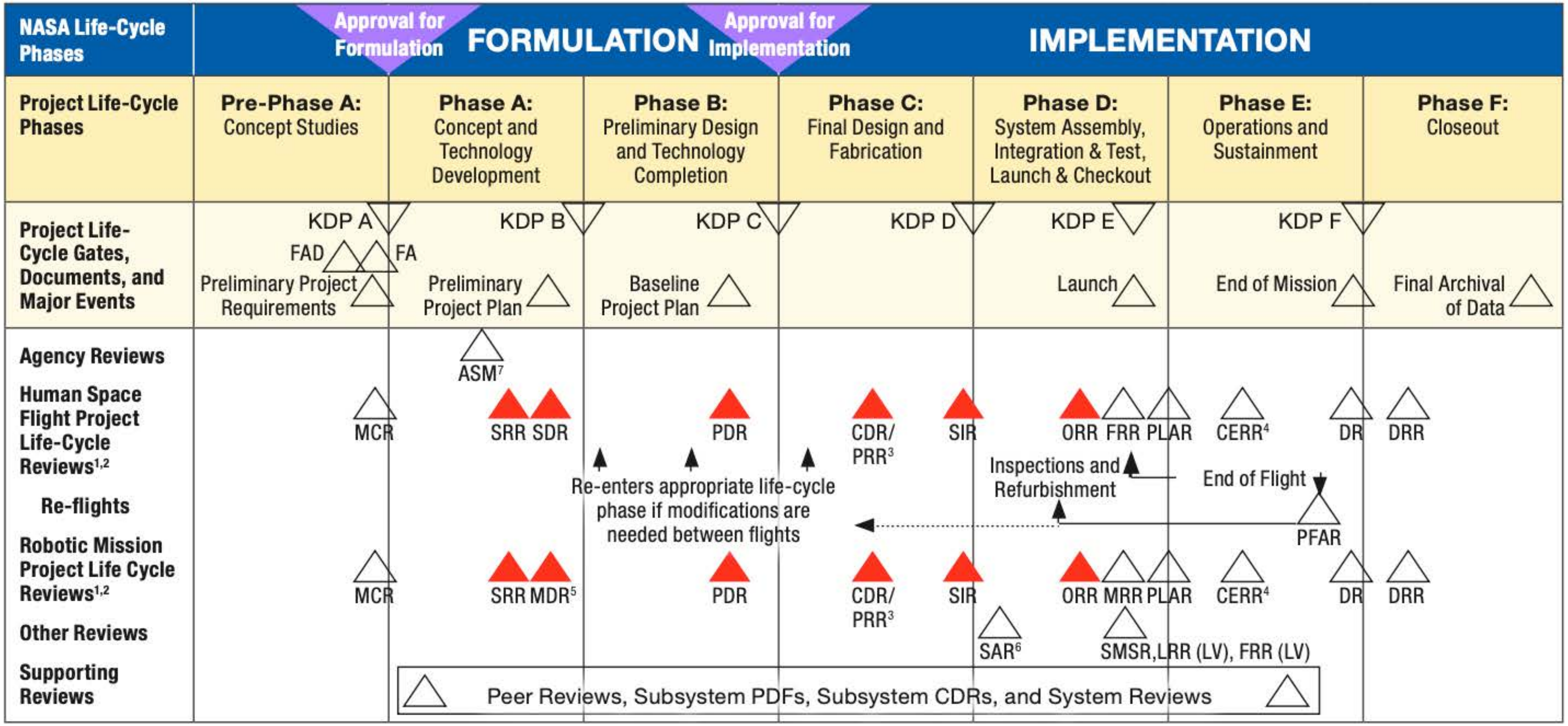


MCR	Mission Concept Review	**CDR**	Critical Design Review
SRR	System Requirements Review	**SIR**	System Integration Review
SDR	System Definition Review	**ORR**	Operational Readiness Review
PDR	Preliminary Design Review	**DR/DRR**	Decommissioning/Disposal Readiness Review

Design changes are costly if done too late!

NASA Mission Life Cycle

From NASA SE Handbook



FOOTNOTES

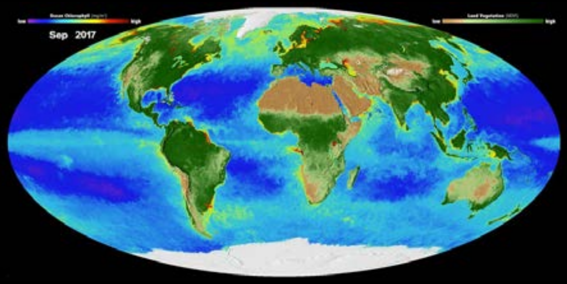
1. Flexibility is allowed as to the timing, number, and content of reviews as long as the equivalent information is provided at each KDP and the approach is fully documented in the Project Plan.
2. Life-cycle review objectives and expected maturity states for these reviews and the attendant KDPs are contained in Table 2-5 and Appendix D Table D-3 of this handbook
3. PRR is needed only when there are multiple copies of systems. It does not require an SRB. Timing is notional.
4. CERRs are established at the discretion of program .
5. For robotic missions, the SRR and the MDR may be combined.
6. SAR generally applies to human space flight.
7. Timing of the ASM is determined by the MDAA. It may take place at any time during Phase A.

▲ Red triangles represent life-cycle reviews that require SRBs. The Decision Authority, Administrator, MDAA, or Center Director may request the SRB to conduct other reviews.

ACRONYMS

ASM – Acquisition Strategy Meeting
CDR – Critical Design Review
CERR – Critical Events Readiness Review
DR – Decommissioning Review
DRR – Disposal Readiness Review
FA – Formulation Agreement
FAD – Formulation Authorization Document
FRR – Flight Readiness Review
KDP – Key Decision Point
LRR – Launch Readiness Review
LV – Launch Vehicle
MCR – Mission Concept Review
MDR – Mission Definition Review
MRR – Mission Readiness Review
ORR – Operational Readiness Review
PDR – Preliminary Design Review
PFAR – Post-Flight Assessment Review
PLAR – Post-Launch Assessment Review
PRR – Production Readiness Review
SAR – System Acceptance Review
SDR – System Definition Review
SIR – System Integration Review
SMSR – Safety and Mission Success Review
SRB – Standing Review Board
SRR – System Requirements Review

The Life Cycle Actually Works and Makes Sense



PACE Science

New opportunities to monitor fisheries and respond to toxic algae blooms, and key ocean and atmosphere data for forecasting air quality and weather that will improve our understanding of Earth's climate.

Mission Commitments (Post-Pandemic Replan):

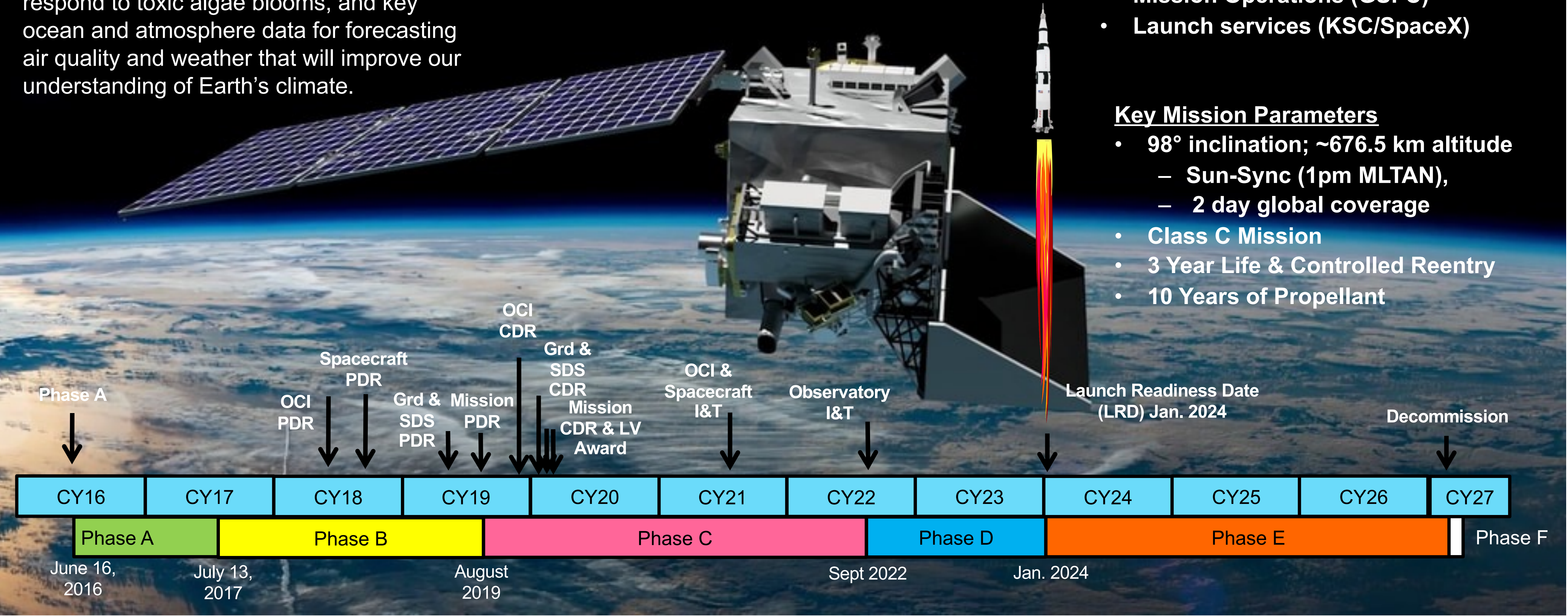
- Management Agreement:
  - LRD January 9, 2024
  - Budget $928.2M ($107.5M for HQ Science)
- Agency Baseline Commitment:
  - Launch Date of May 2024
  - Budget of $964M

Mission Elements (Organization)

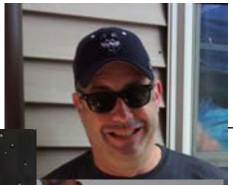
- Competed Science Team (NASA ESD)
- Vicarious Calibration (NASA ESD)
- Science Data Analysis (GSFC)
- Ocean Color Instrument (GSFC)
- Spacecraft (GSFC)
- Polarimeters (SRON & UMBC)
- Mission Operations (GSFC)
- Launch services (KSC/SpaceX)

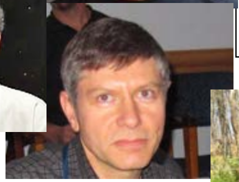
Key Mission Parameters

- 98° inclination; ~676.5 km altitude
  - Sun-Sync (1pm MLTAN),
  - 2 day global coverage
- Class C Mission
- 3 Year Life & Controlled Reentry
- 10 Years of Propellant



Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) Project





Applications Coord.
E. Urquhart
Deputy Coord.
N. Sadoff

Project Scientist
J. Werdell
Deputy Proj. Scientist (Ocean)
A. Mannino
Deputy Proj. Sci. (Atmosphere)
B. Cairns

616

PACE Project Manager
M. Voyton

Deputy Project Manager
J. Lander

Deputy Project Manager / Resources
W. Sluder

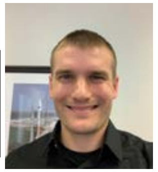
427

616

Science Data Segment Manager
B. Franz

155.2

Financial Management Specialist
M. Gosselin/C. Greco



Resource Analyst
S. Braha
C. Higgins

Earned Value Management
R. Hesenperger


Mission Systems Engr
G. Davis
Deputy MSE
N. Haghani

599

Systems Engineers
C. Stevens.
R. Zellar
J. Eitnier
R. Kraeuter
J. Patel
J. Ong
S. Glubke
T. Gruner
L. Sparr
K. McGinnis

383

Chief Safety and Mission Assurance Officer
B. Weidema

Software Assuranc
N. Basant
Quality
F. Fried
Reliability
P. Pruessner
Safety
A. Obaldo

Sr. Project Support Manager
K. Opperhauser

General Business
P. Blackwood

Schedule Management
M. Burtenshaw

Configuration / Data Management
L.Sullivan/L.Mryncza/K.Radspinner

Video Imaging & Photo. Rqmnts
D. Henry

Information Technology
C. Jorgenson
T. Ferm
R. Hager– IT Security Officer

Observatory Manager
B. Weinstein

568

I & T Manager
V. Pinnick
Deputy I & T Mgr.
K. Tull

Mission & Ground Operations Manager
R. Schweiss

581

472

Launch Vehicle Mgr.
J. Satrom

LSP / KSC - SPACEX

OCI Project Mgr.
R. Estep
OCI Deputy PM
C. Koca

497

Systems Engineers
E. Gorman

543

Launch Site Manager
K. Hughes

Elec. I&T
J. Savinell
GSE
K. Blahut
IT
C. Jorgenson

Technician
J. Wilson
Purge
M. Sharb
Mech. I&T
K. Harris

Test Conductor
M. Patel
Alignment
S. Hetherington
Thermal I&T
D. Powers

497

Polarimeter Instrument Manager
D. Kujawa

Hyper - Angular Rainbow Polarimeter 2 (HARP2) - UMBC

Spectro - Polarimeter for Exploration (SPEXone) - SRON

Avionics
R. Gheen
Contamination
J. Sanders
Elec/Harness
H. Manalo

Flt. Software
M. Blau
GDS
J. Gallun
GN&C
P. Mason

Materials
M. Shacka
Mechanical
K. Harris
Mechanisms
C. Monroe

M. Ortiz-Acosta
Propulsion
H. Mulkey

Radiation
R. Ladbury
RF Comm
A. Rodriguez-Arroyo
Thermal
D. Powers

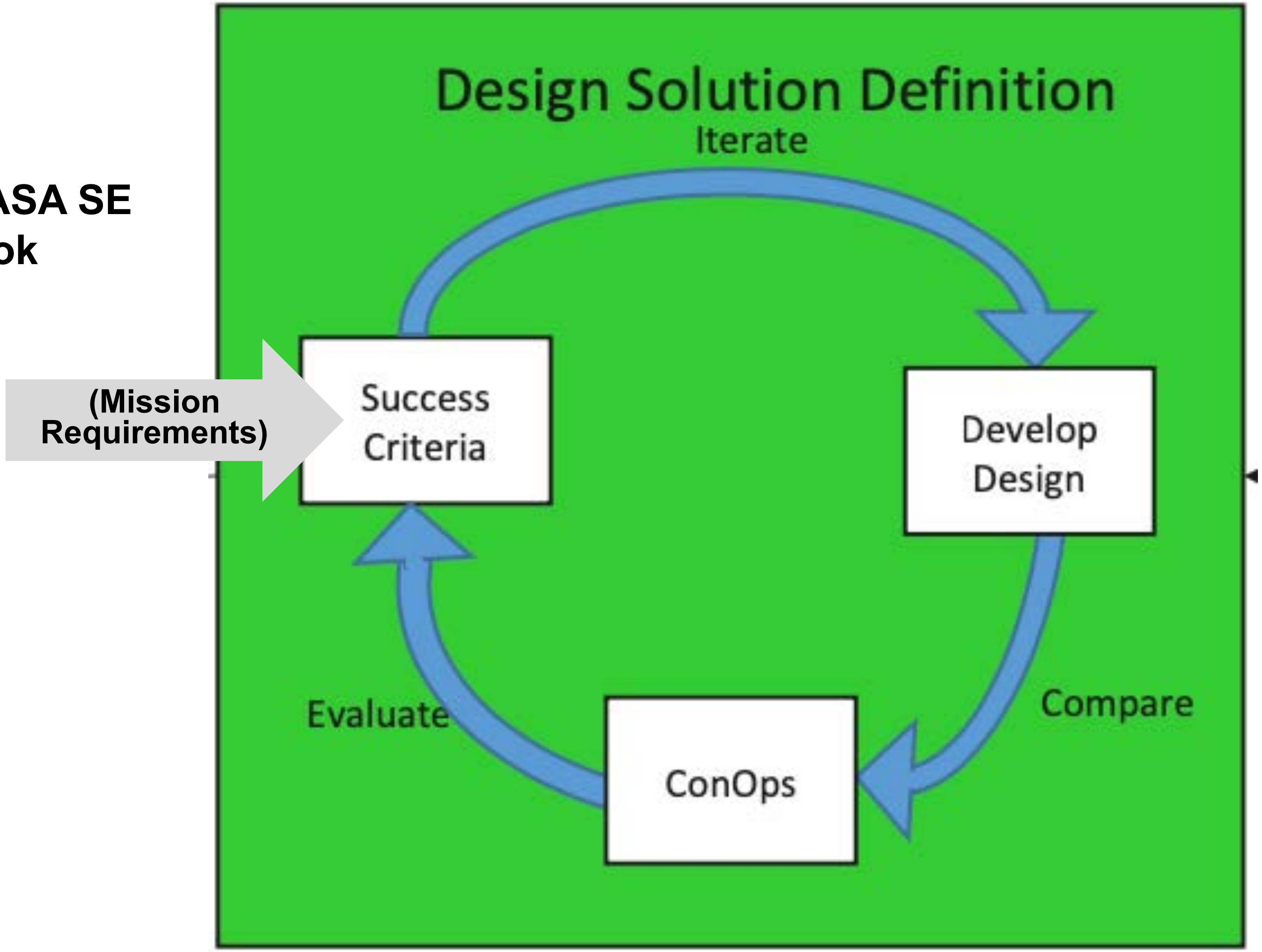
The Team is your most precious and capable resource!

Mission Design:

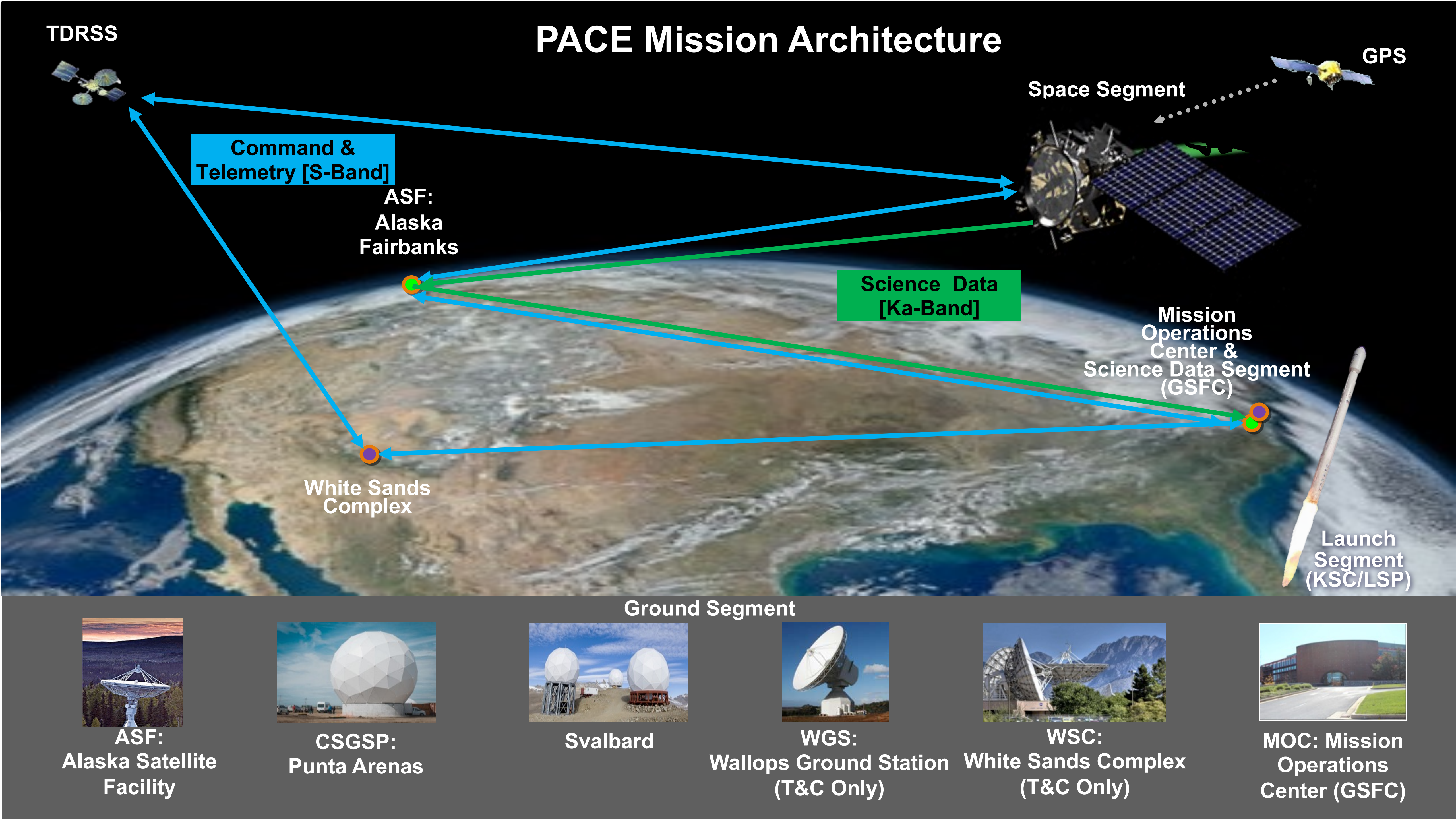
- Requirements
- Design
- Ops

Design Spiral

From NASA SE Handbook



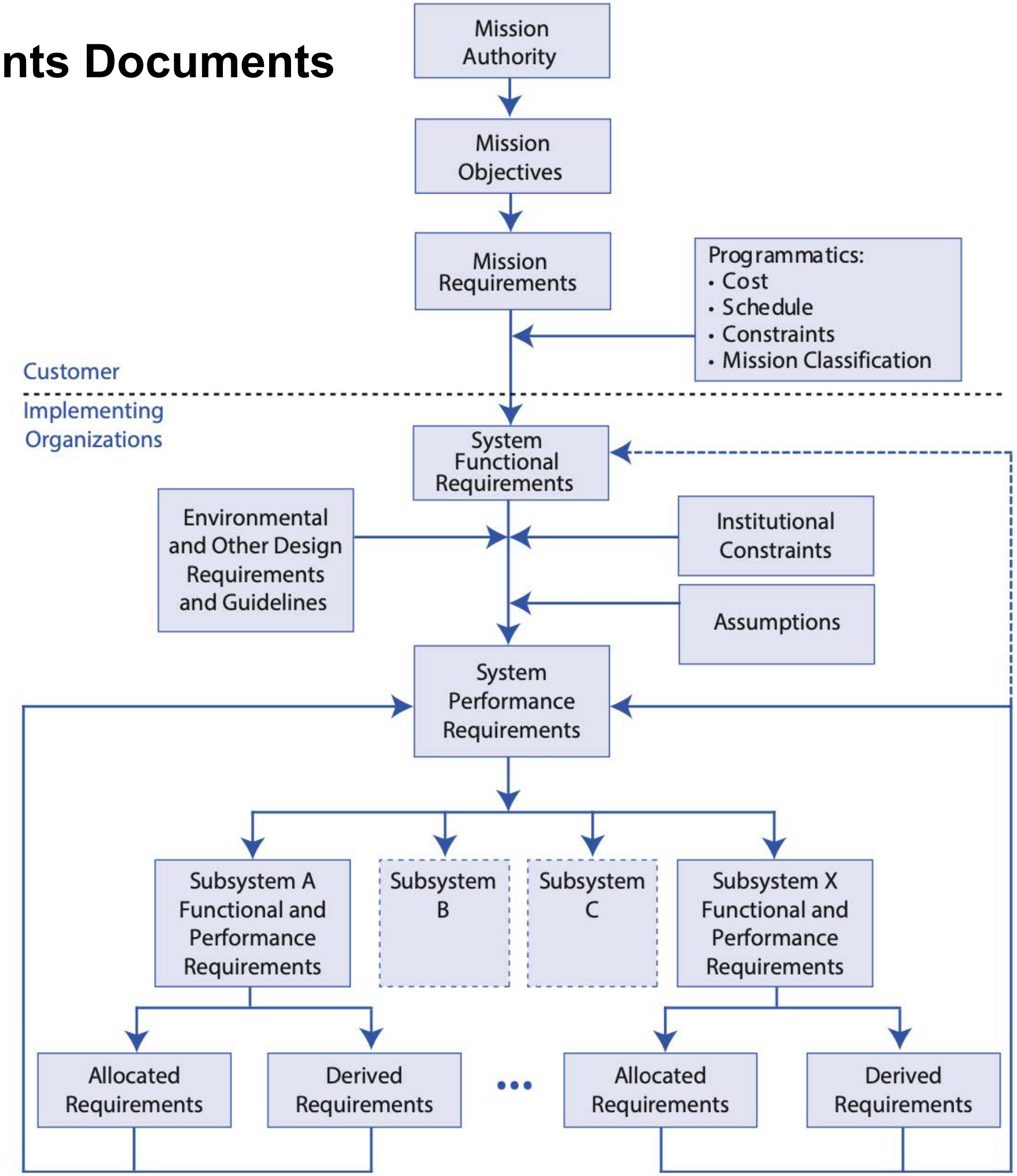
Perfection is elusive. Analysis paralysis can waste time.



PACE Mission Architecture
TDRSS
GPS
Space Segment
Command &
Telemetry [S-Band]
ASF:
Alaska
Fairbanks
Science Data
[Ka-Band]
Mission
Operations
Center &
Science Data Segment
(GSFC)
White Sands
Complex
Launch
Segment
(KSC/LSP)
Ground Segment
ASF:
Alaska Satellite
Facility
CSGSP:
Punta Arenas
Svalbard
WGS:
Wallops Ground Station
(T&C Only)
WSC:
White Sands Complex
(T&C Only)
MOC: Mission
Operations
Center (GSFC)

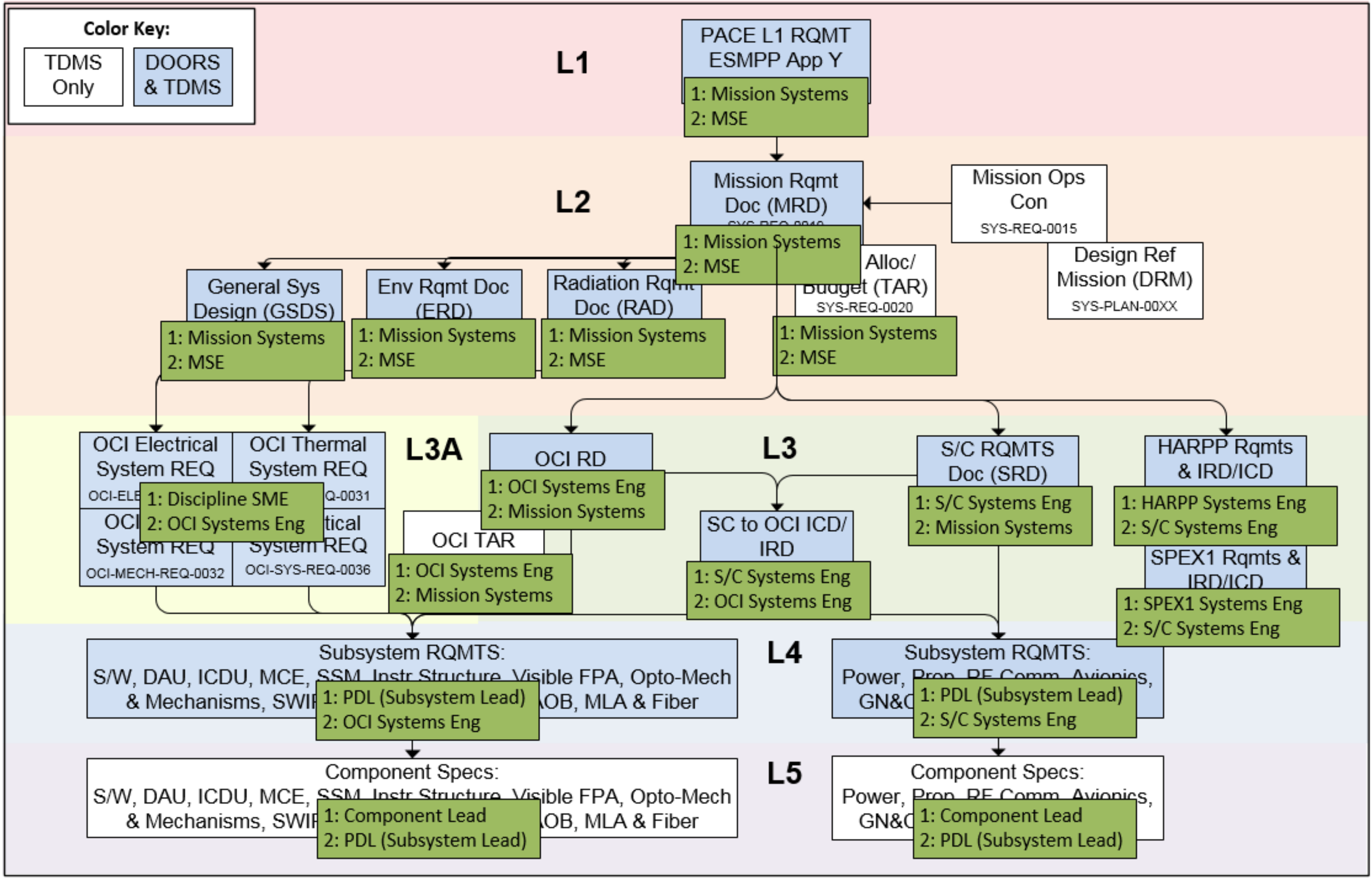
Mission Requirements Documents

From NASA SE Handbook



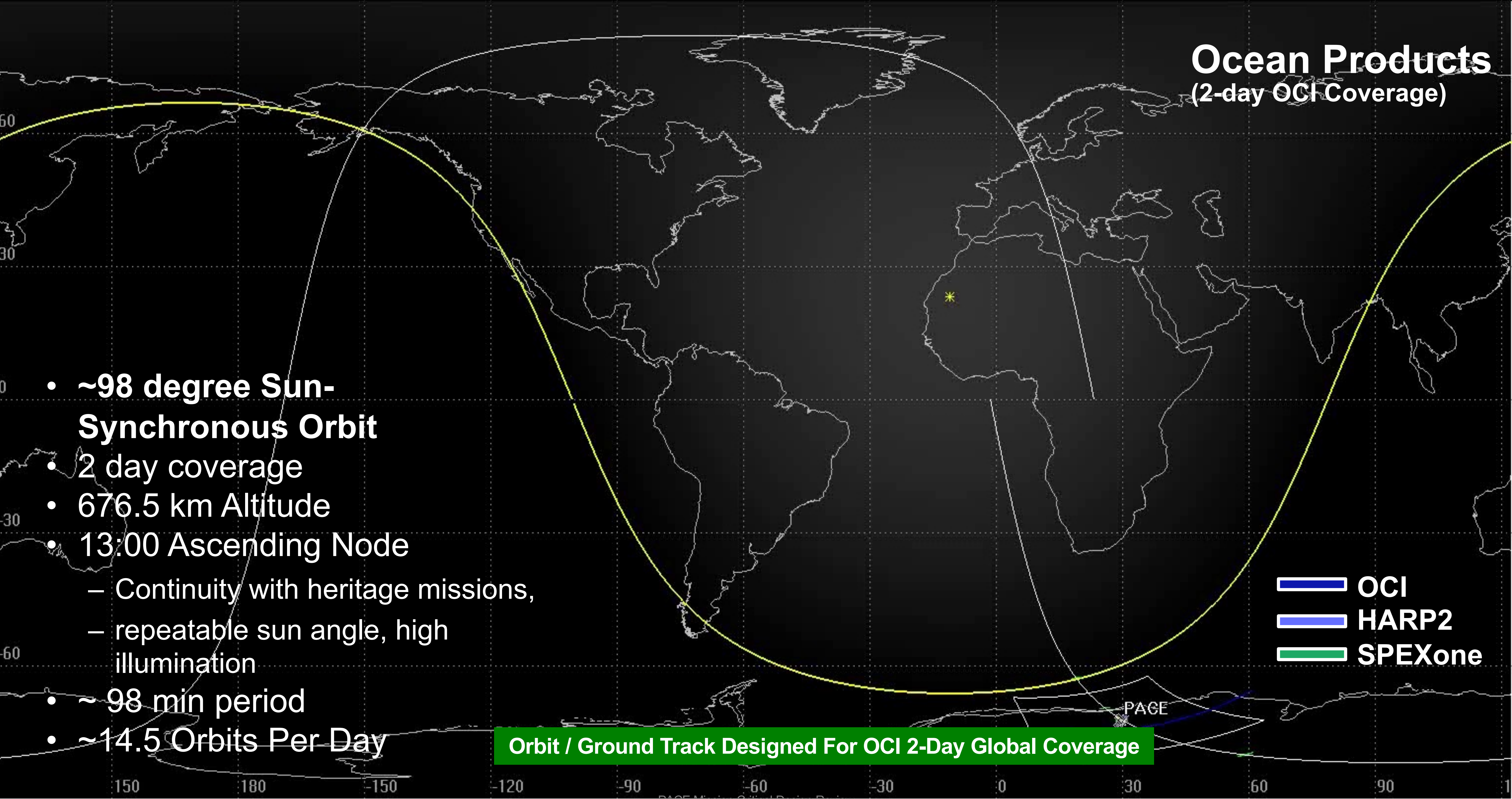
Organized from top-level to many many details at lower levels

From PACE V&V Plan



Ocean Products
(2-day OCI Coverage)

- **~98 degree Sun-Synchronous Orbit**
- 2 day coverage
- 676.5 km Altitude
- 13:00 Ascending Node
  - Continuity with heritage missions,
  - repeatable sun angle, high illumination
- ~ 98 min period
- ~14.5 Orbits Per Day



Orbit / Ground Track Designed For OCI 2-Day Global Coverage

PACE Observatory Design Overview

What does this thing have to do?

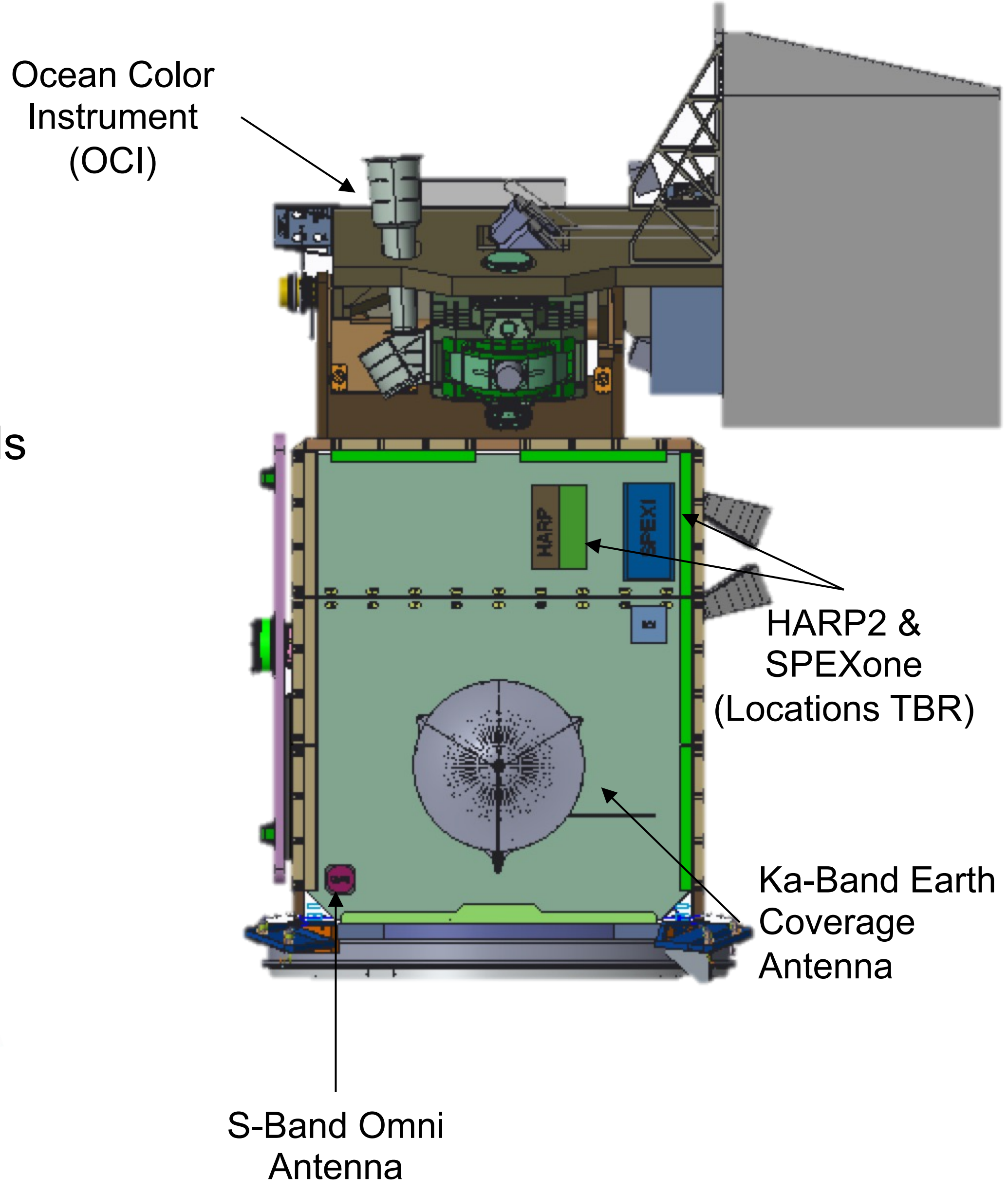
Support three instruments
Point in weird ways
Get data to the ground

All while surviving space . . . . for three years:

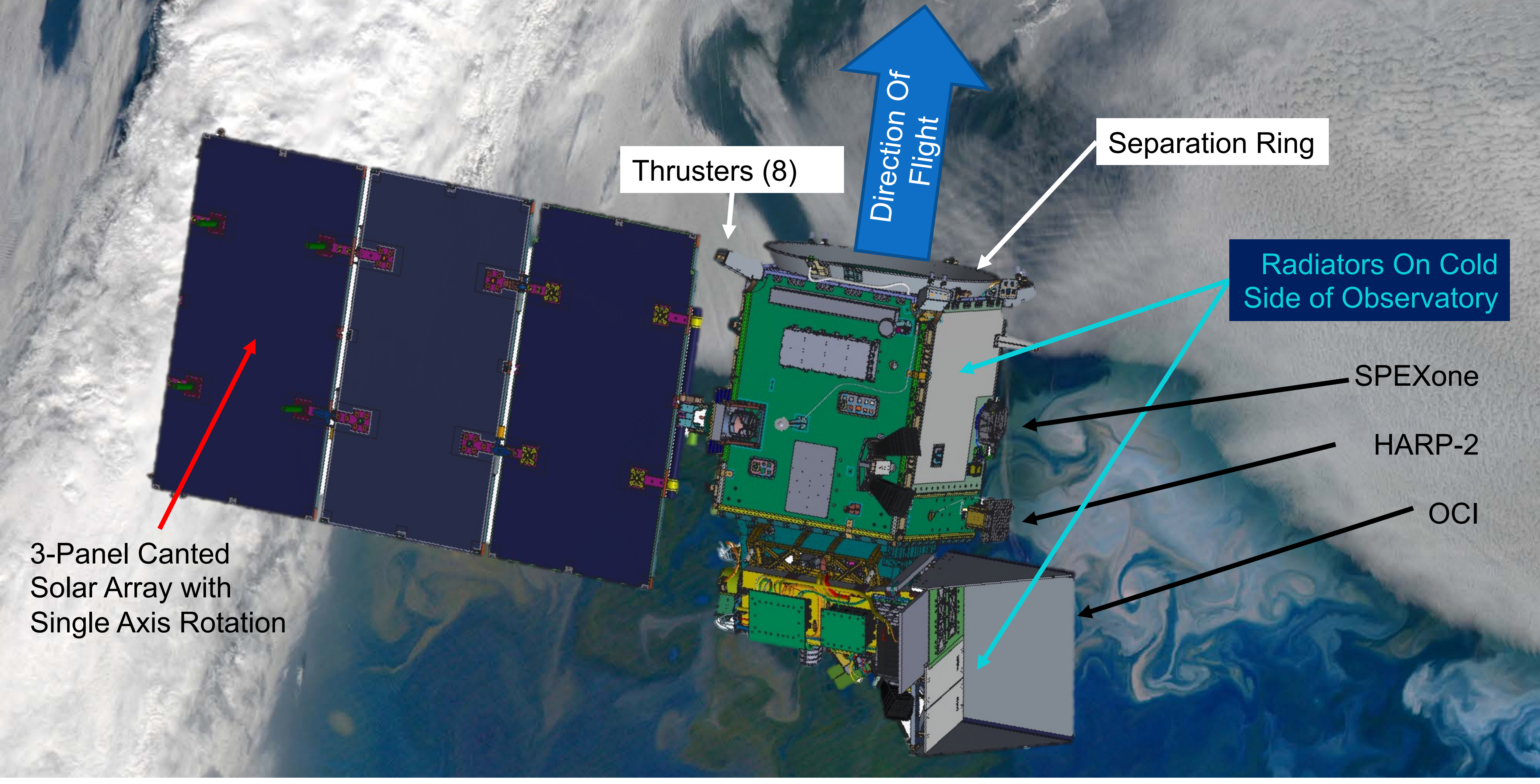
Not too cold, but not too hot!
Surviving vibration & acoustics & launch loads
Radiation, thermal cycles,
  atomic oxygen, MMOD
Don’t cost too much!
  (but be the best you can)

Once science mission is over:

Controlled de-orbit into the Pacific Ocean



PACE Observatory Layout: Why does it look like this?

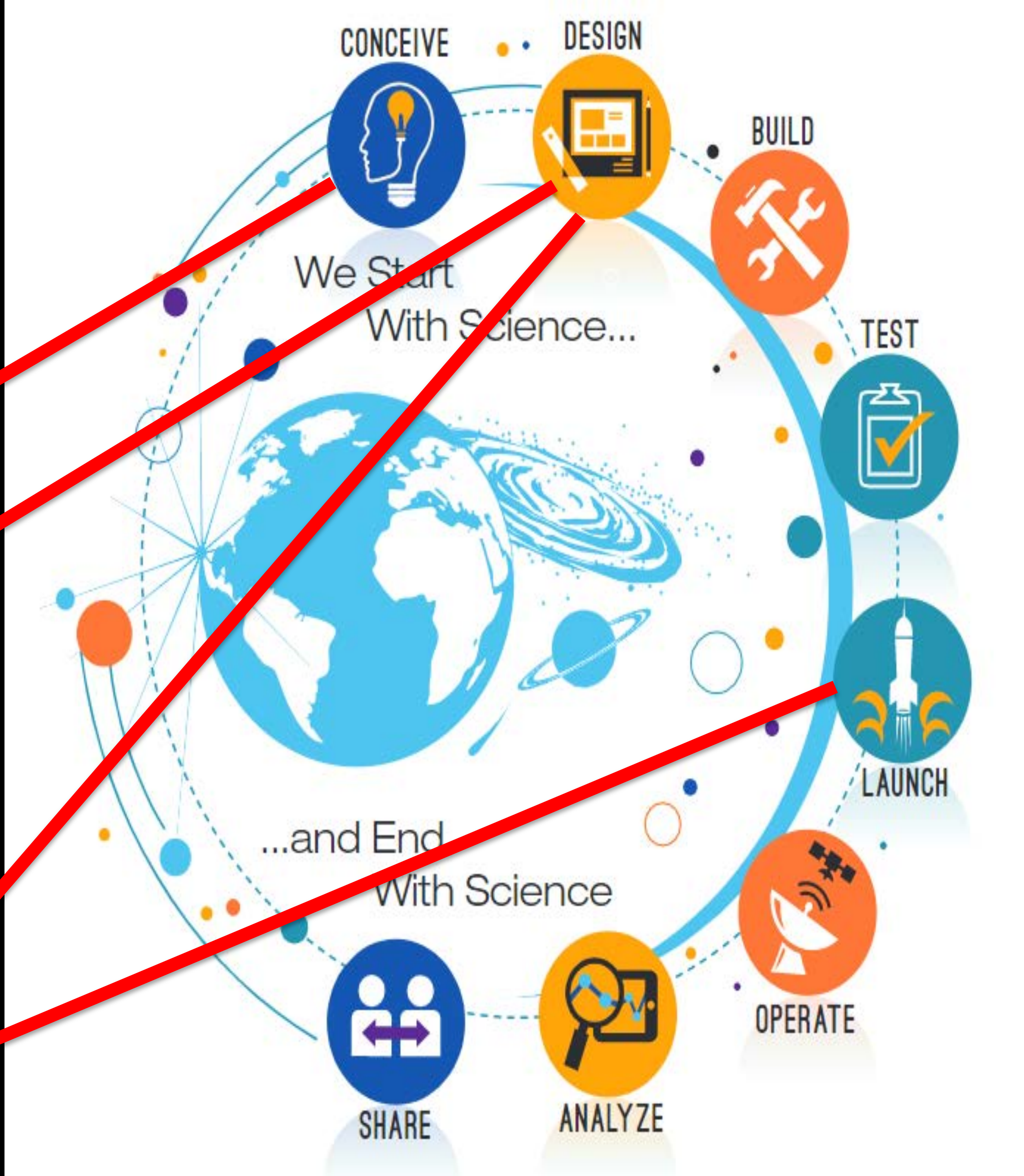


- Design phase challenges on PACE?

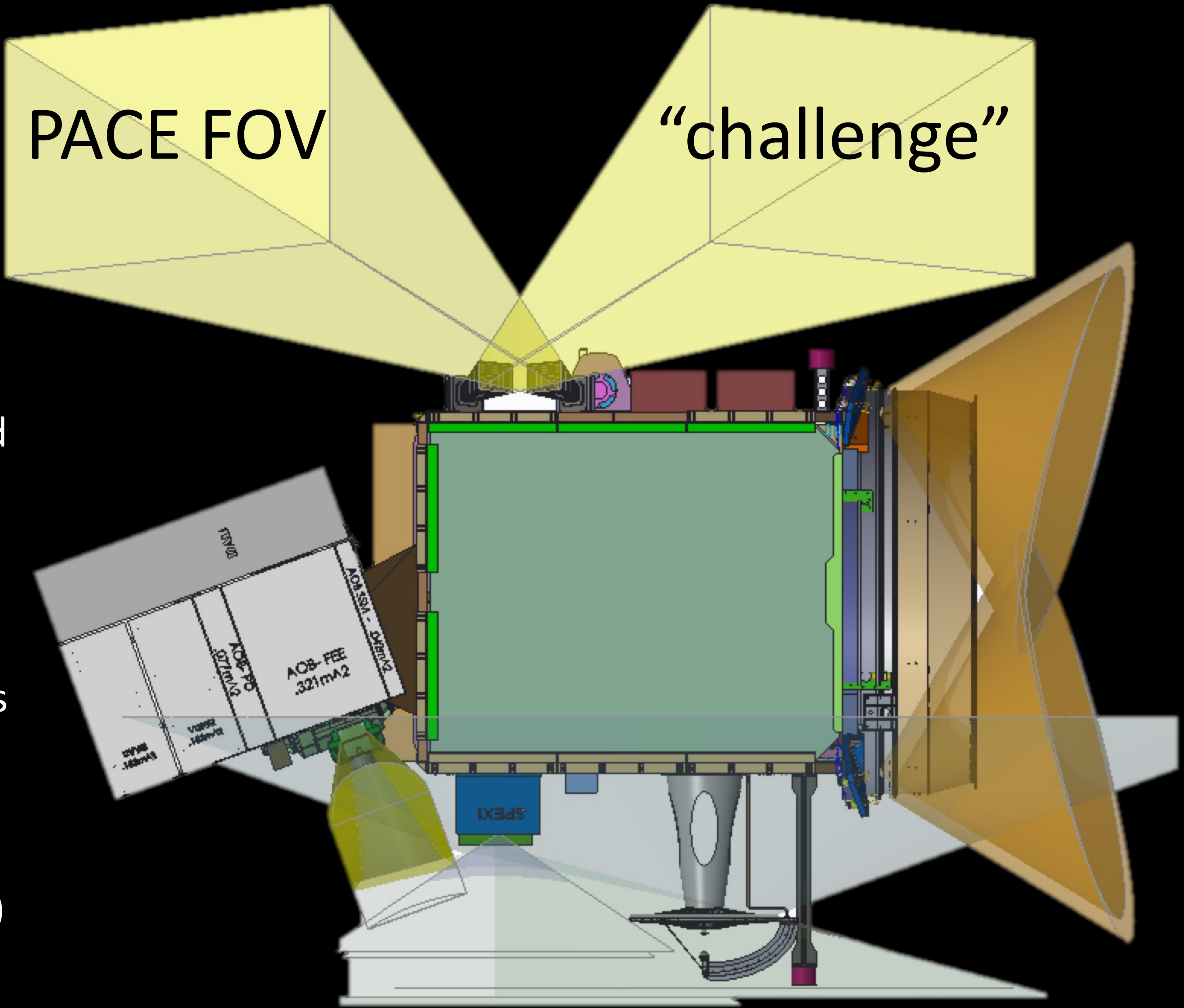
- Overall:
  - Stormy weather surrounded the Federal Budget

- OCI Instrument:
  - Optics/Detectors/ packaging/mechanisms

- Design To Cost:
  - Architecture changes
  - Launch Vehicle is unknown



- Solar array (rotating)
- Instrument thermal radiators
- Earth shield
- Spacecraft radiators
- Sun sensors (13)
- Star cameras (3)



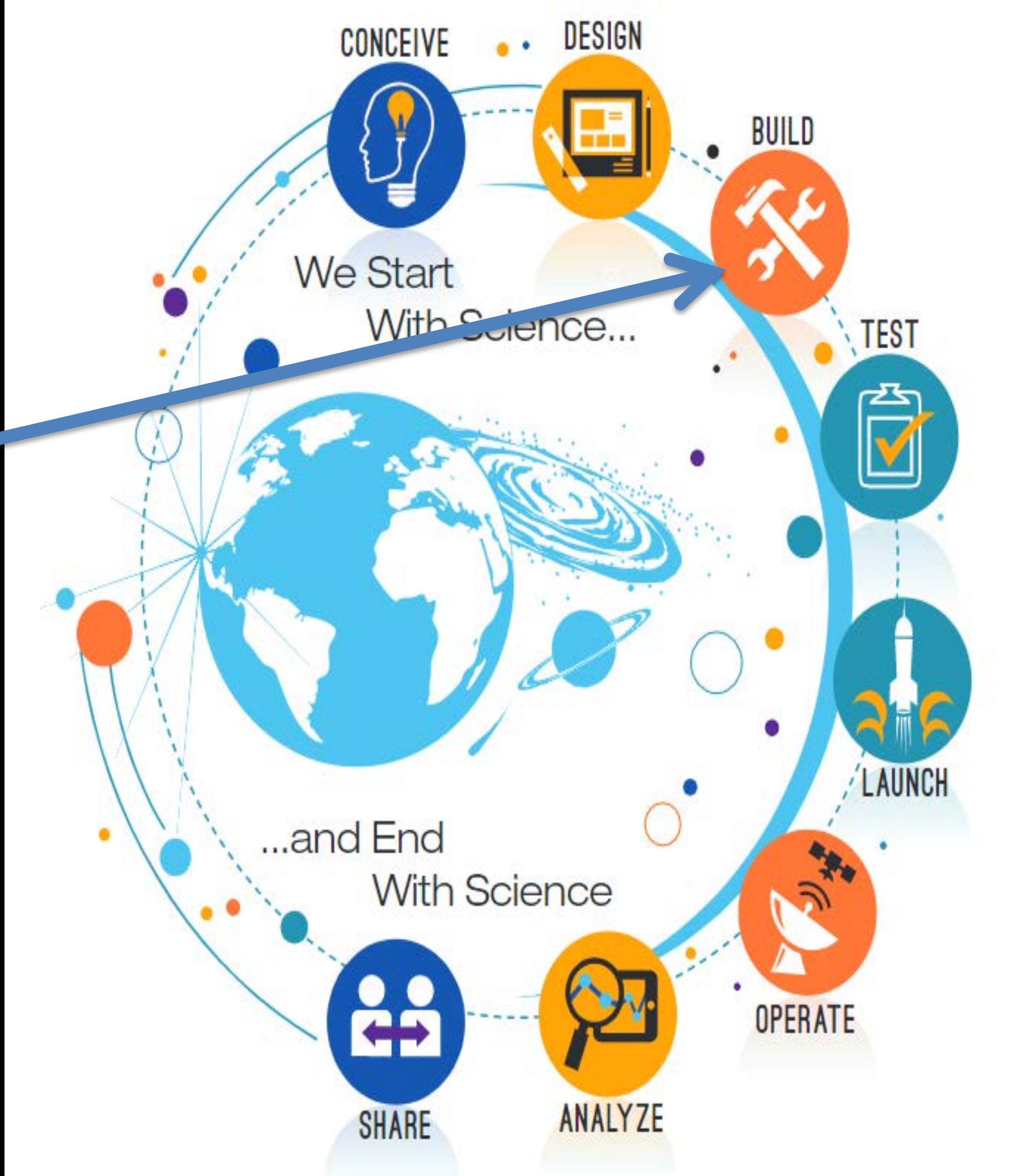
- OCI primary optics
- OCI solar cal
- OCI SPCA telescope
- HARP optics
- SPEX optics (5)
- Thrusters (8)
- Ka antenna
- S-band antenna (2)

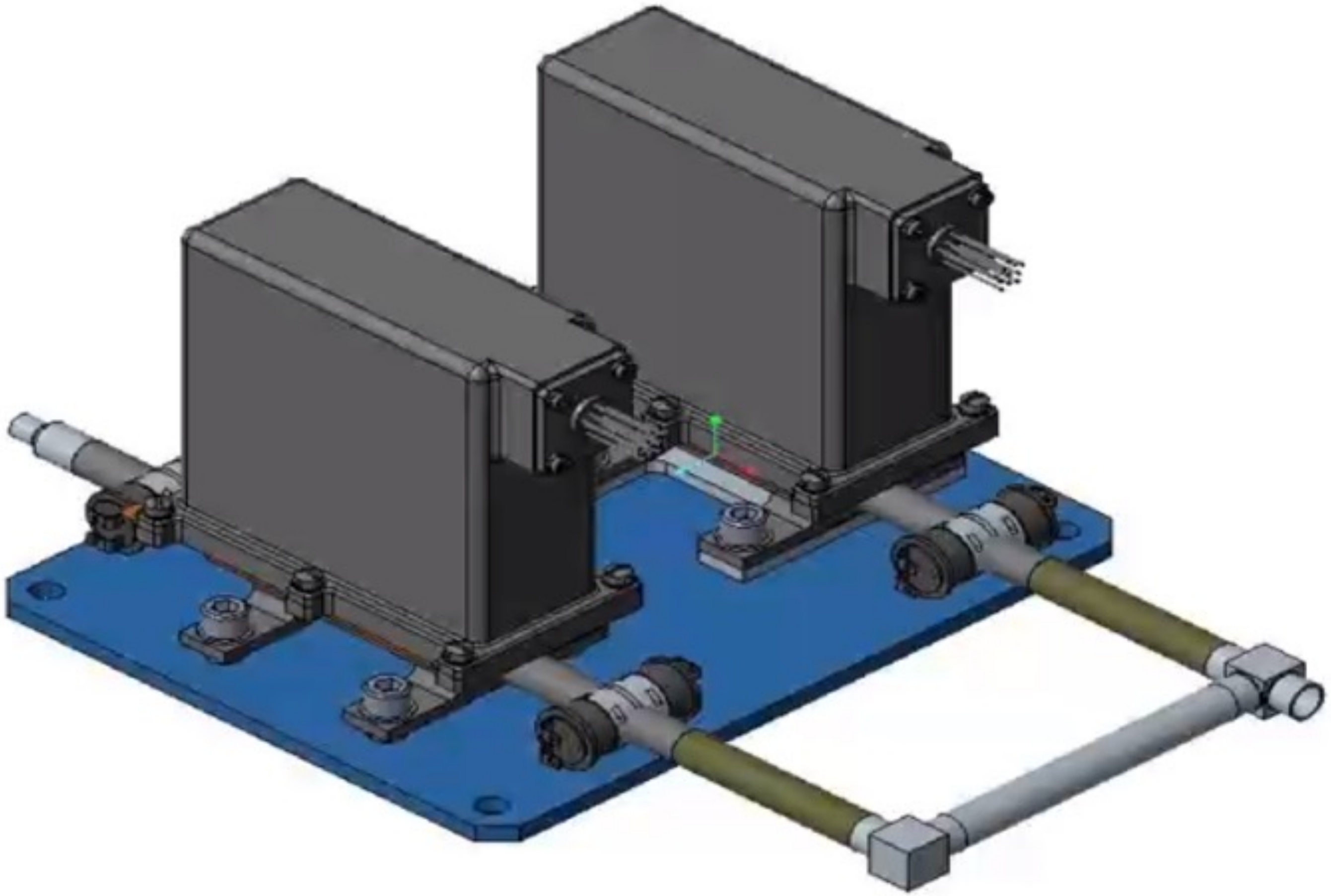
Build:

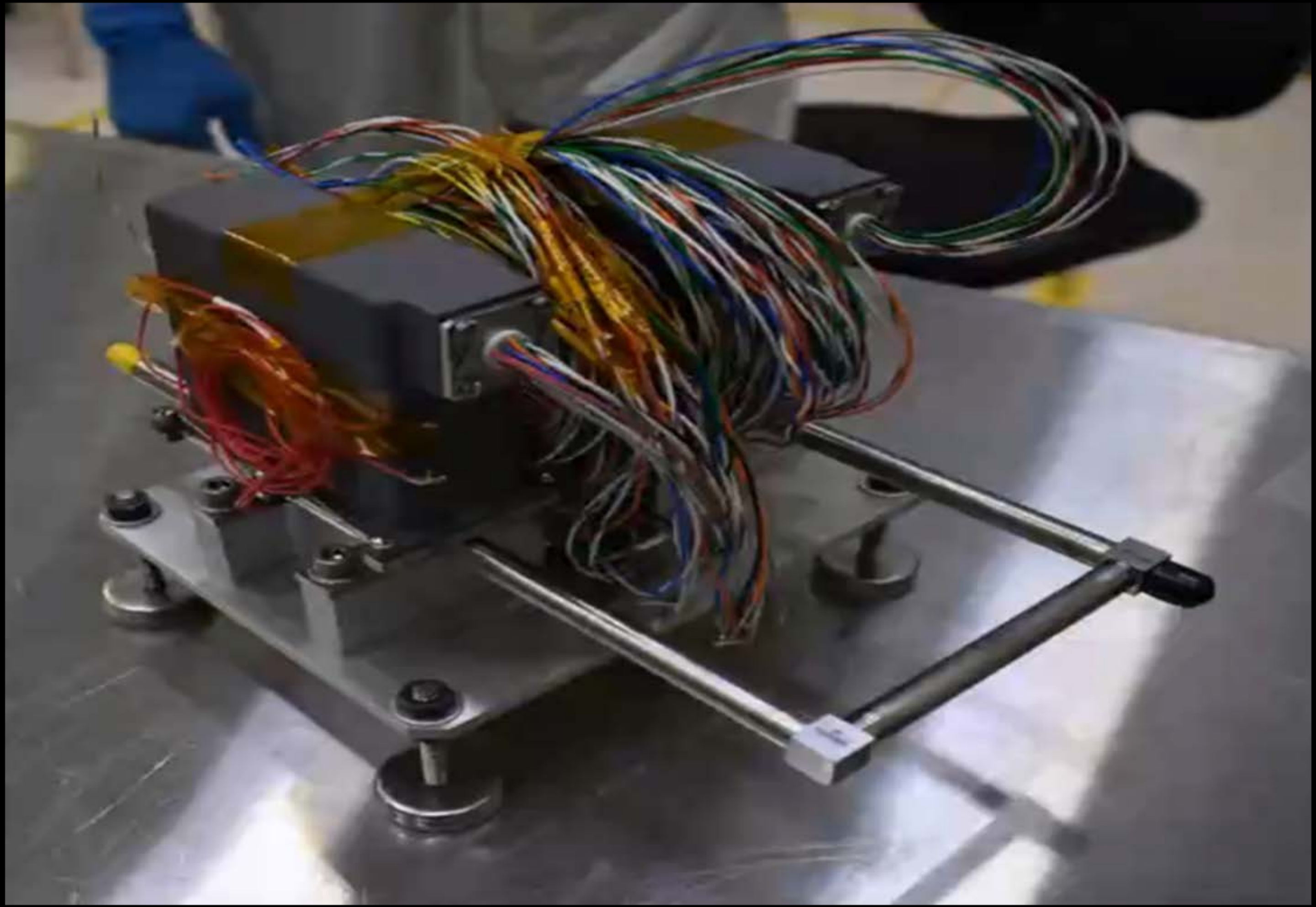
– This is the “I” in “I&T”

(unless you are from California or Colorado)

– Typically the fun part

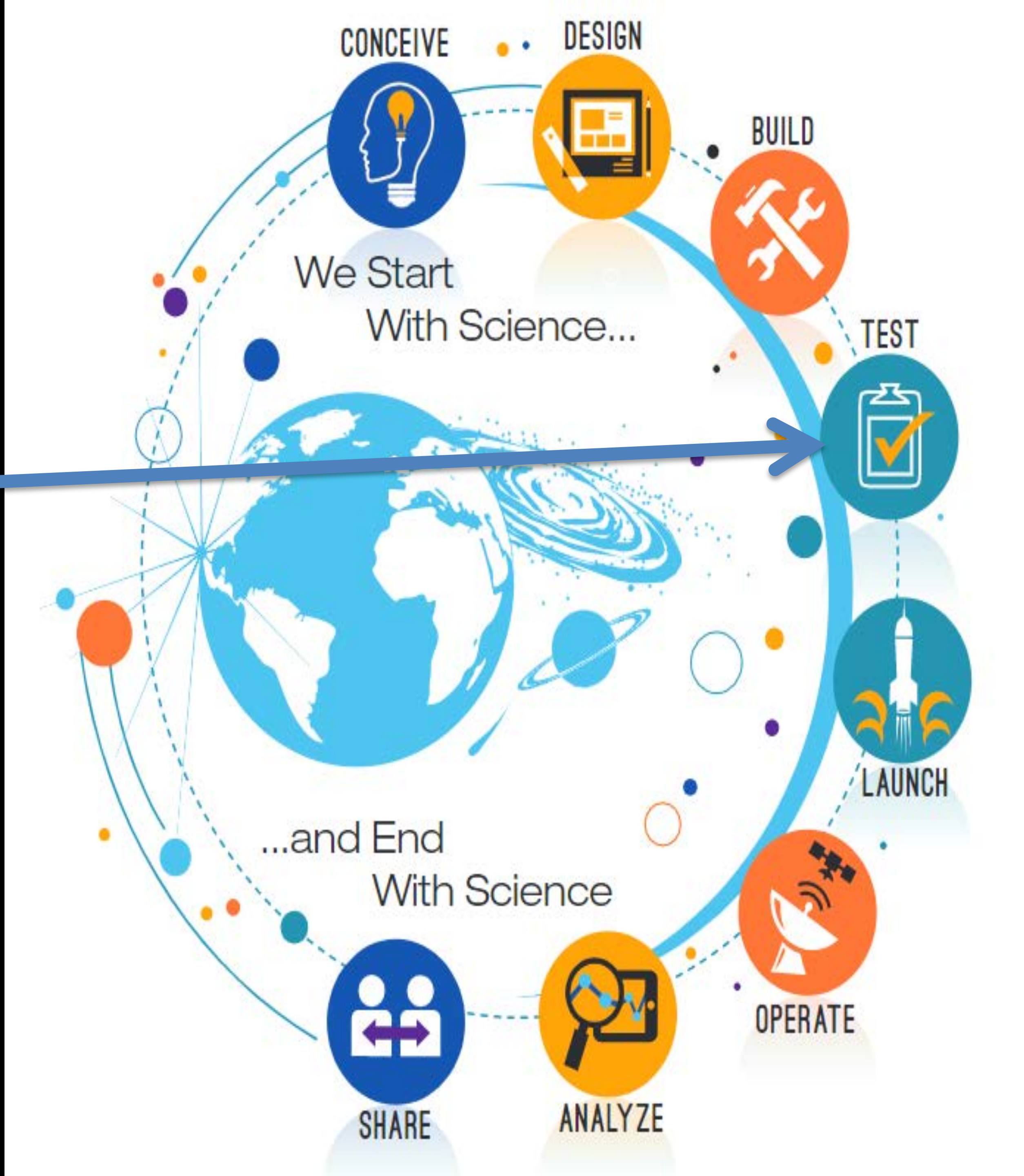






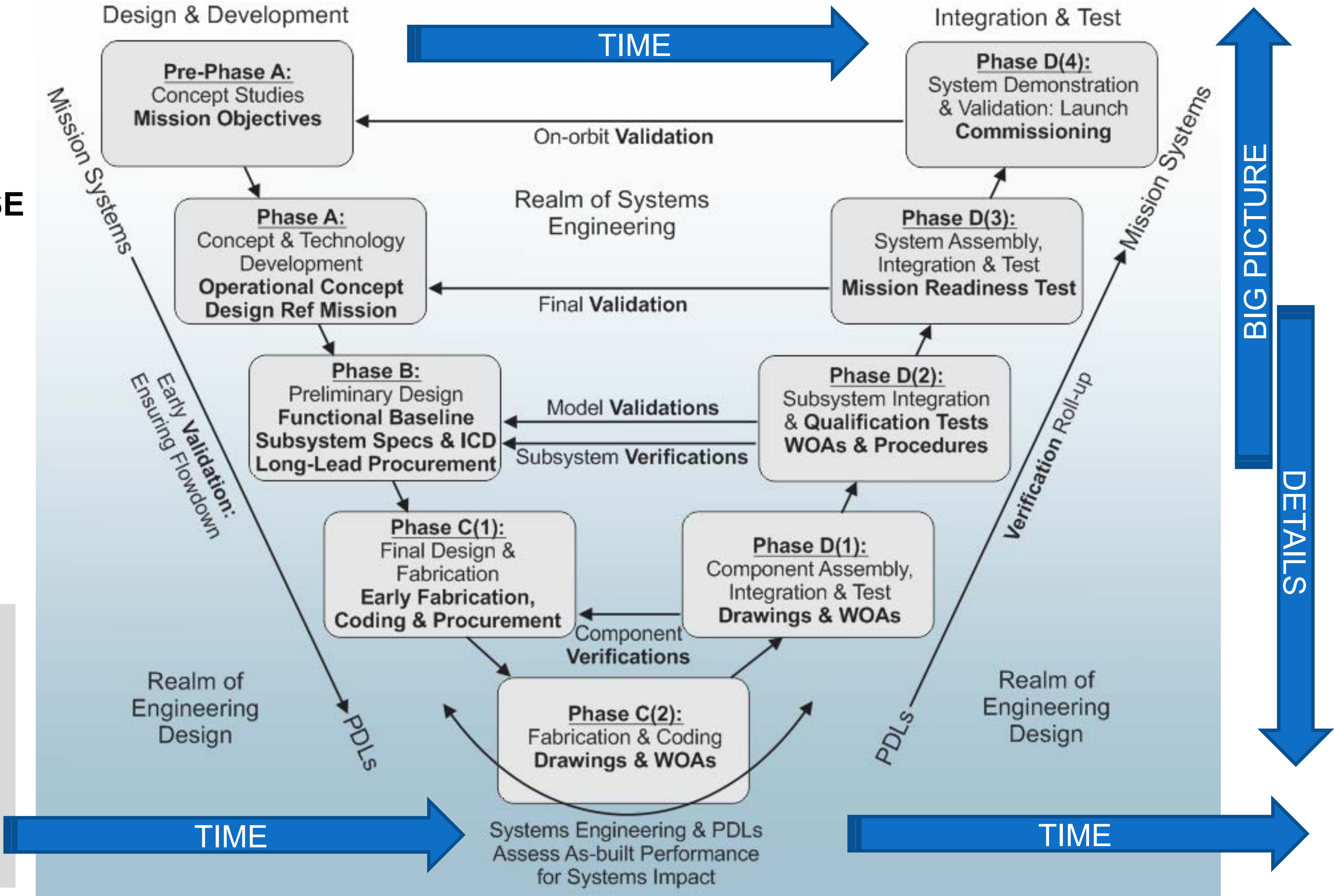
Test:

- This is the "T" in "I&T"
- Can be the fun part, if you like to break stuff and fix stuff and never sleep

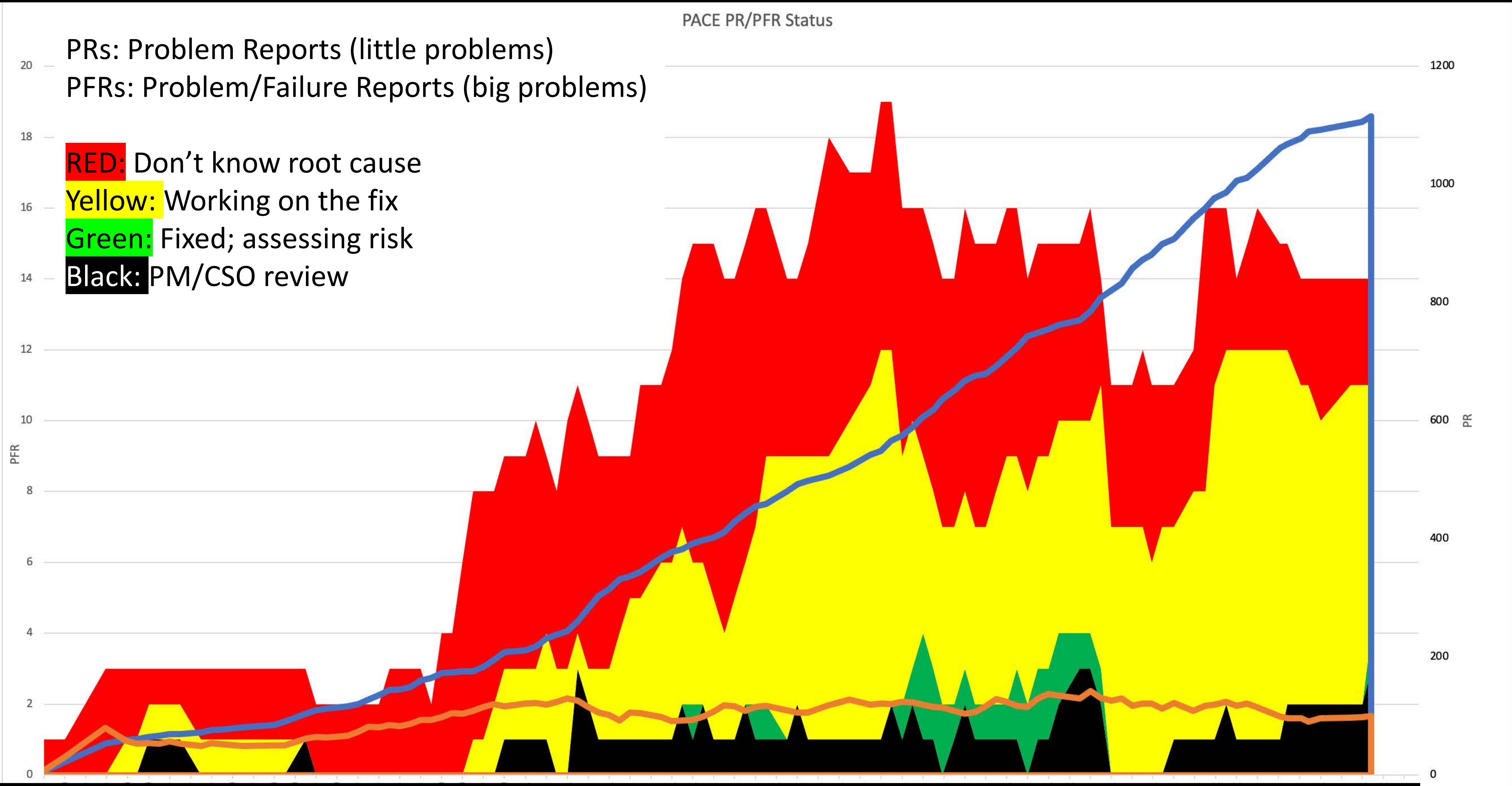


Verification & Validation "VEE"

From NASA SE Handbook



This process works, but it messier that the diagram suggests!



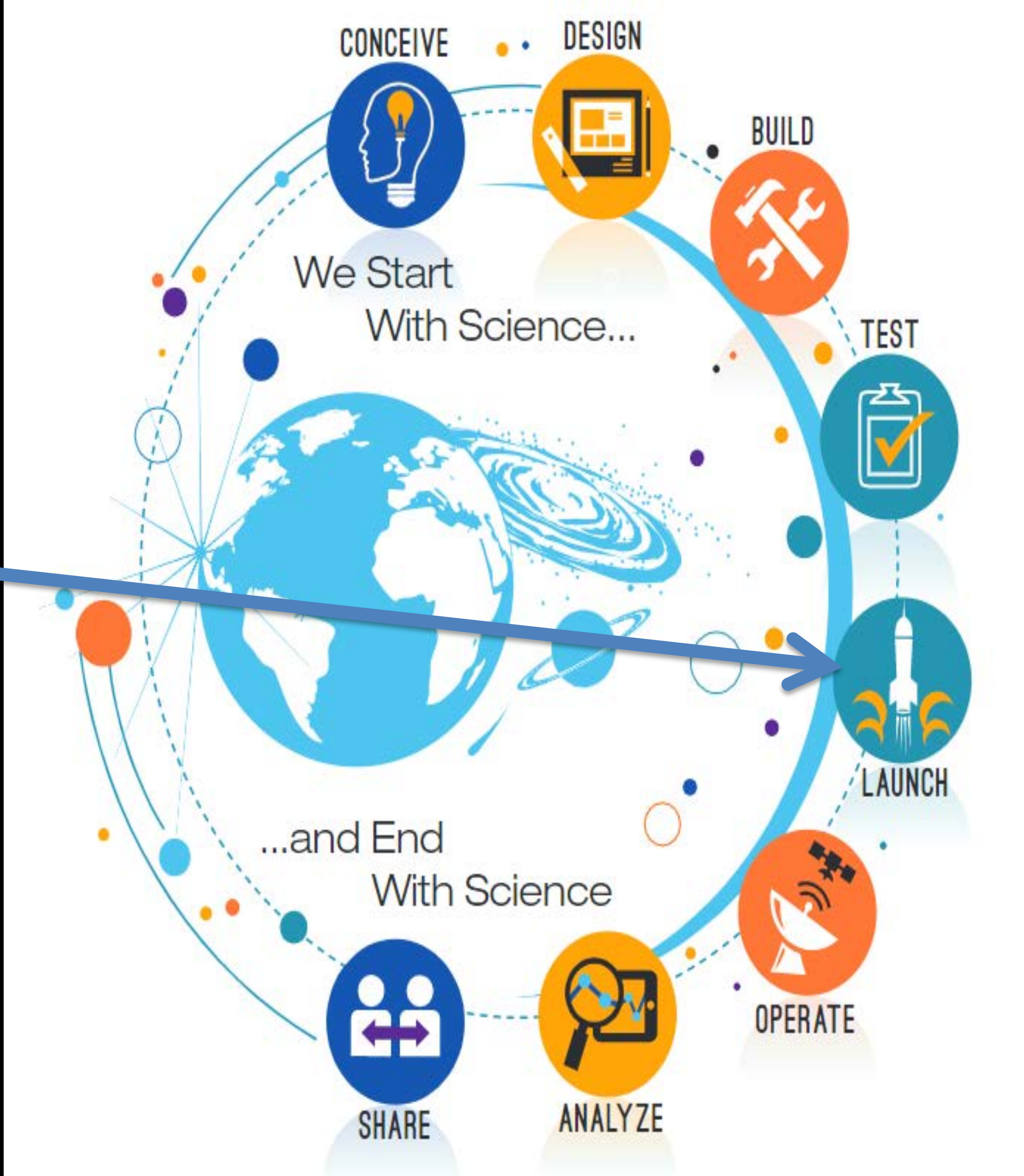
Problems are going to happen; our PFR process is robust and very useful.

Launch:

– Nerves of steel

– Team gets divided in two!

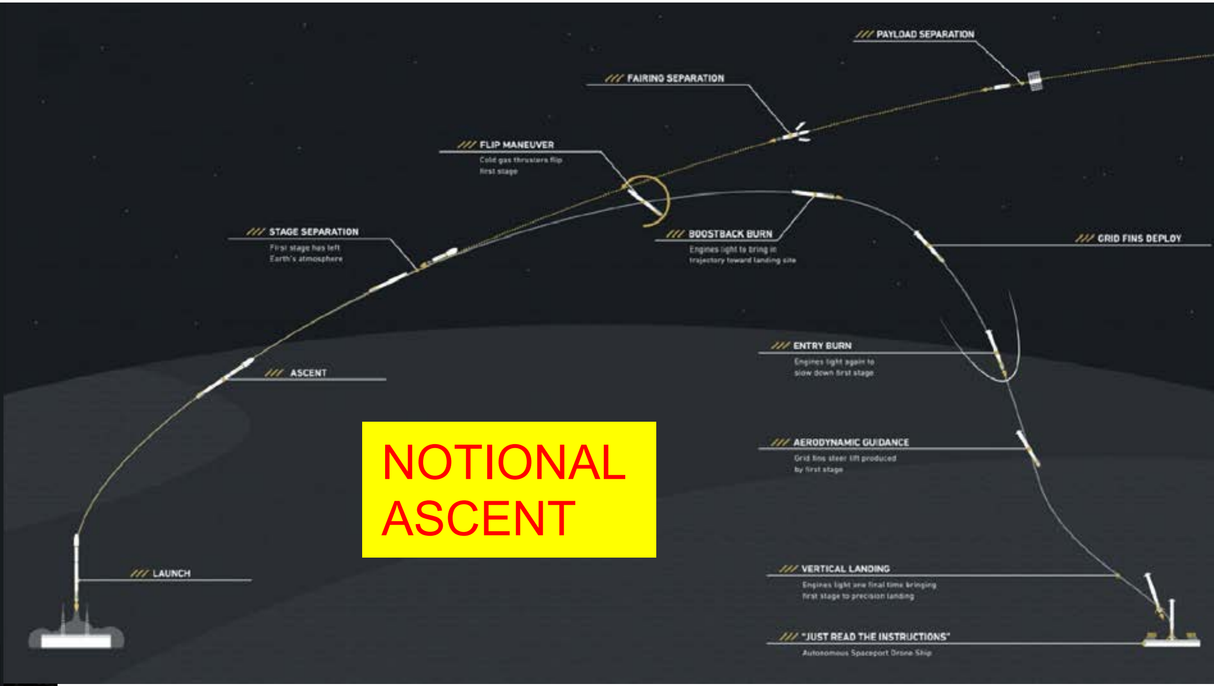
- Fun lucky few
- Miserable cold rest

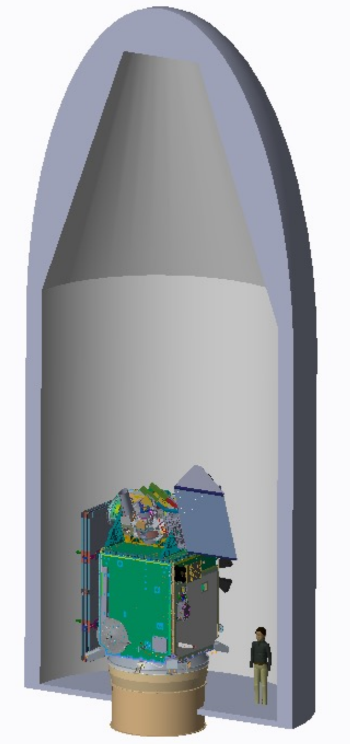


PACE Launch Vehicle is a FALCON 9

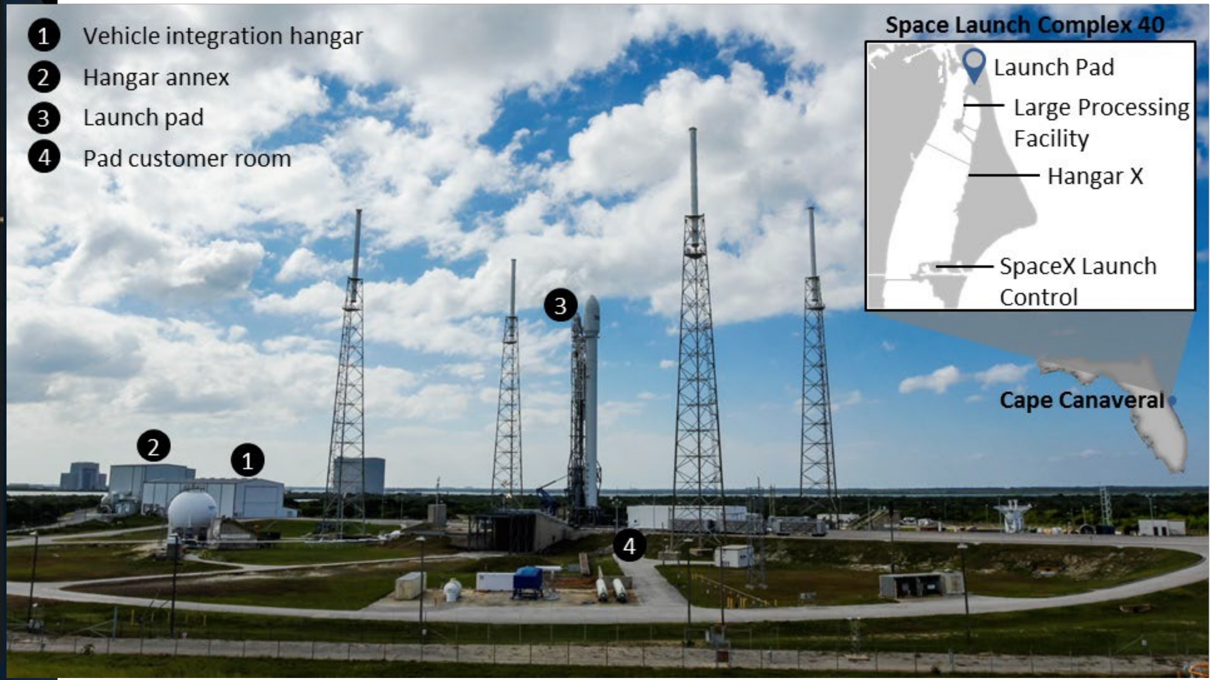
- Award selection made public on 4 Feb 2020

- Using a flight-proven booster
- No ESPA/rideshare simplify integration & flight ops
- Plenty of room in the fairing; T-0 purge
- Launch site is CCSFS/KSC
- Performance gets PACE to orbit on direct ascent
- Similar trajectory to SAOCOM-1B





CX-40 at CCAS/KSC



Launch Site Team Environment

Flight Ops Team Environment

6 Feb 2010

6 Mar 2015

OREX Launch Video

I stole the clips; I am no Kurosawa.

I stole the music; I am no Williams.

Personal use only; do not make any money from it.

Apologies to Lightning McQueen, ULA, Lockheed, GSFC!

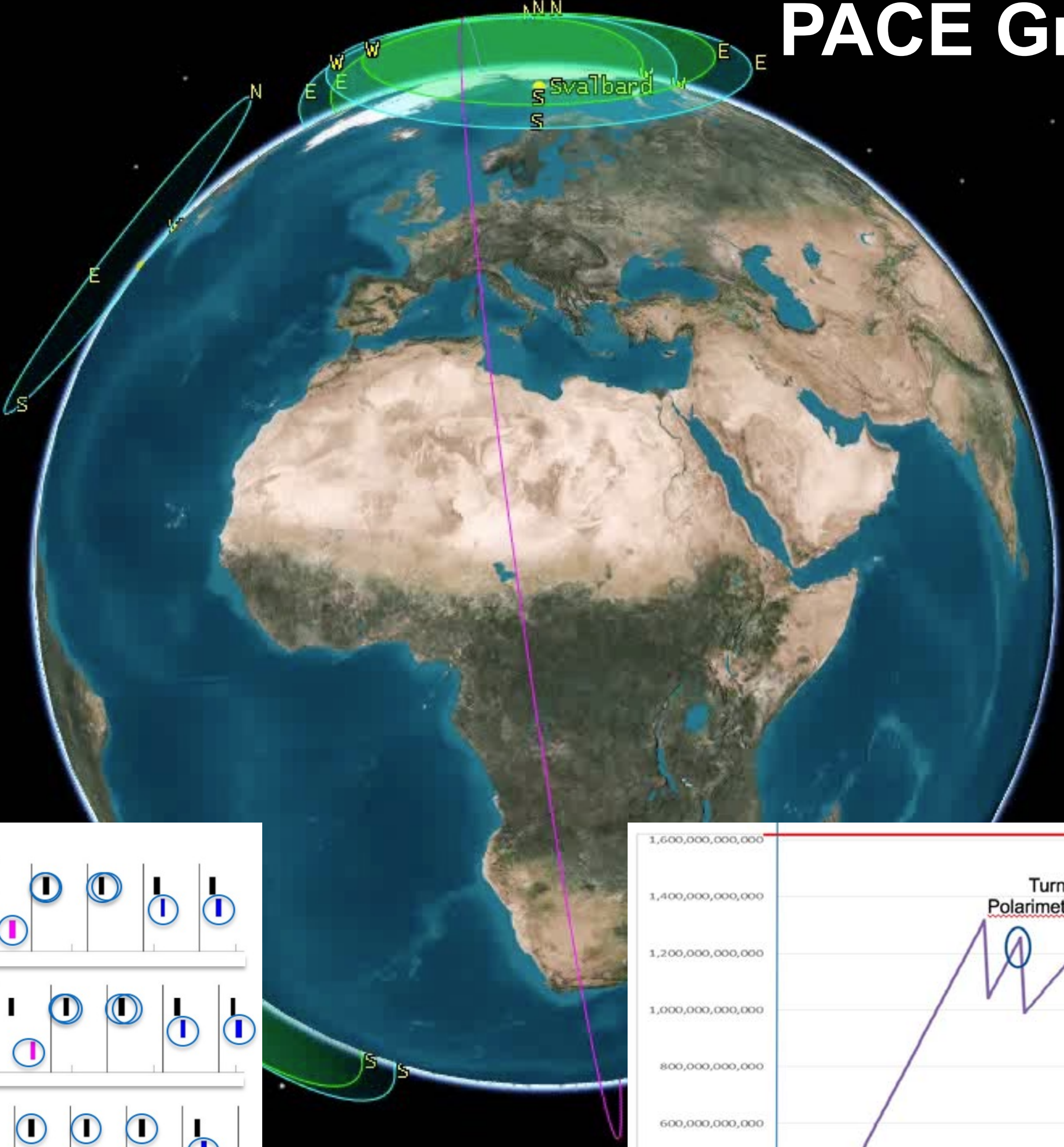
Mission Ops:

Don’t get creative

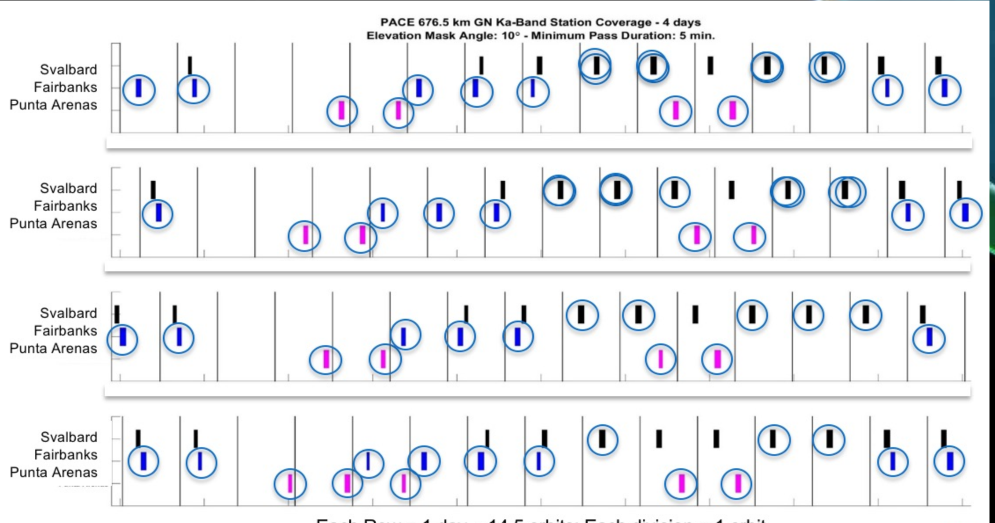
PACE Ground Contacts

- Four NEN stations:
- Fairbanks (Ka & S-band)
- Punta Arenas (Ka & S-band)
- Svalbard (Ka & S-band)
- Wallops (S-band only)

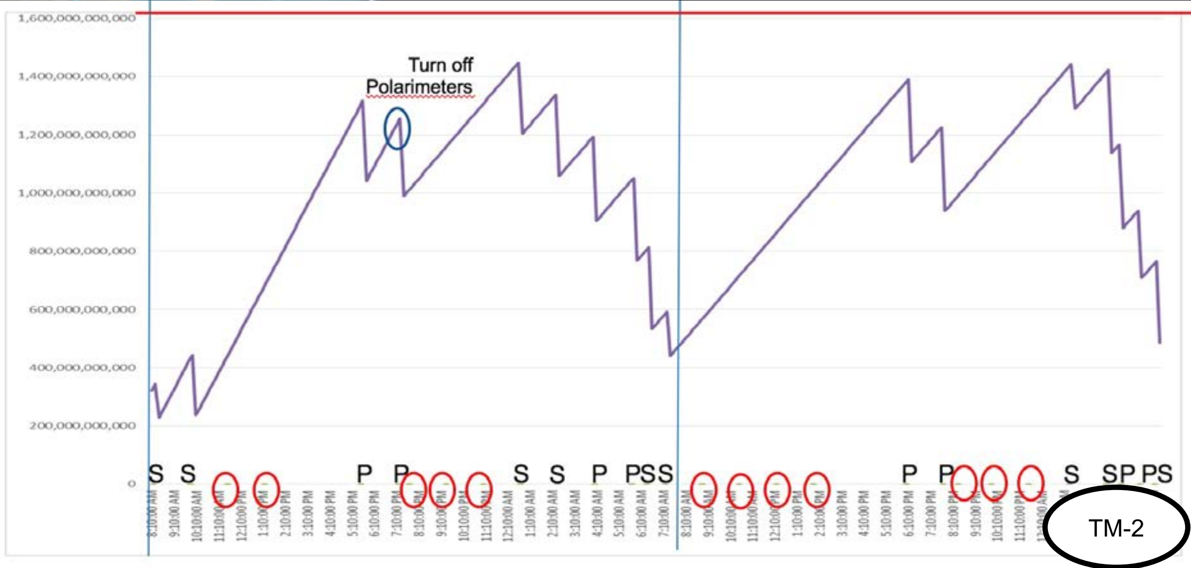
- ~ 21.5 possible Ka contacts per day
- PACE requires ~14.5 per day to keep up with data collected.



If a Ground Station goes down, we can turn off Polarimeters and still collect all OCI Data



Each Row = 1 day, ~14.5 orbits; Each division = 1 orbit
Required contacts circled in blue



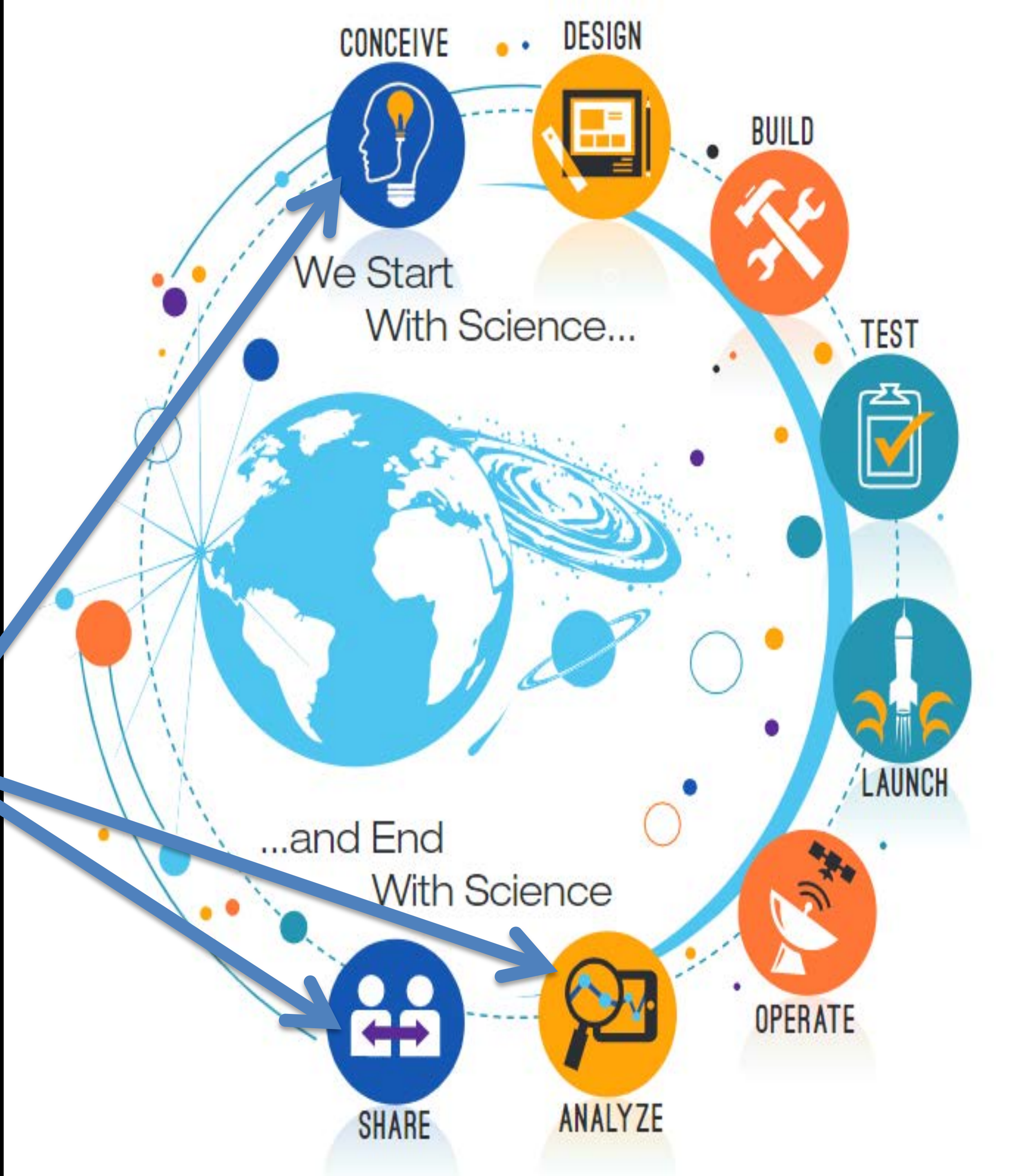
End of Ops:

Turn off the spacecraft ☹

Safe ocean disposal

Then it's back to the science wizards:

Ask more questions so we can do another mission!



CONCLUDING THOUGHT

"The flying machine which will really fly might be evolved by the combined and continuous efforts of mathematicians and mechanicians in from one million to ten million years"

The New York Times
9 Oct 1903

"We started assembly today"

Orville Wright's Diary
9 Oct 1903

¿ Questions ?