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!

No ITAR Material
Bios: Who was I before PACE?
PACE Mission Systems: What do we do?

Zany Scientists’ Ideas

“Proposal Phase”

Pre-Phase-A

Technology Studies
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. ∆cost for ∆change 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

Design changes are costly if done too late!
### NASA Mission Life Cycle

**From NASA SE Handbook**

The Life Cycle Actually Works and Makes Sense

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<th>NASA Life-Cycle Phases</th>
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**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 optional.
4. CERRs are established at the discretion of the 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.

**ACRONYMS**

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<th>ASM – Acquisition Strategy Meeting</th>
<th>MRR – Mission Readiness Review</th>
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<td>CDR – Critical Design Review</td>
<td>ORR – Operational Readiness Review</td>
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<td>PDR – Preliminary Design Review</td>
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<td>DRR – Critical Readiness Review</td>
<td>PPR – Post-Flight Assessment Review</td>
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<td>FA – Formulation Agreement</td>
<td>PLR – Post-Launch Readiness Review</td>
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<td>FFR – Flight Readiness Review</td>
<td>SDR – System Definition Review</td>
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<td>KDP – Key Decision Point</td>
<td>SIR – System Integration Review</td>
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<td>LRR – Launch Readiness Review</td>
<td>SMSR – Safety and Mission Success Review</td>
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<td>LV – Launch Vehicle</td>
<td>SB – Standing Review Board</td>
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<td>MOR – Mission Concept Review</td>
<td>SRR – System Requirements Review</td>
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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

Launch Readiness Date (LRD) Jan. 2024
Decommission

Cy CDR & SDS CDR & LV Award
OCI PDR
OCI & SDS PDR
PDR
Mission PDR
Mission CDR
OCI 
CDR
Launcher
Launch Readiness Date (LRD) Jan. 2024
Decommission

Phase A

Phase B
Phase C
Phase D
Phase E
Phase F

CY16 CY17 CY18 CY19 CY20 CY21 CY22 CY23 CY24 CY25 CY26 CY27
The Team is your most precious and capable resource!
Mission Design:

- Requirements
- Design
- Ops
Design Spiral

Design Solution Definition

Iterate

Success Criteria

Develop Design

Compare

Evaluate

ConOps

(Mission Requirements)

Perfection is elusive. Analysis paralysis can waste time.
Mission Requirements Documents

From NASA SE Handbook

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

Ocean Color Instrument (OCI)
HARP2 & SPEXone (Locations TBR)
Ka-Band Earth Coverage Antenna
S-Band Omni Antenna
Solutions!
PACE Observatory Layout: Why does it look like this?

- 3-Panel Canted Solar Array with Single Axis Rotation
- Thrusters (8)
- Separation Ring
- Direction Of Flight
- Radiators On Cold Side of Observatory
- SPEXone
- HARP-2
- OCI
• 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)

PACE FOV

“challenge”

• 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
Launch Site Team Environment
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
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.
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

“There is no one right answer, but the history of the world will not be written in any language other than that of the people who have written it. And if we cannot write it ourselves, we can still learn about it by studying the people who wrote it.”

—— Orville Wright

“Where the sky meets the earth, there is a place for all men, for all things. There is no place for any thing or any man that is not welcome there.”

—— What Can Be Said about the Earth

“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