



# Satellite Operations 101

## Part 1



# Agenda



- Team Design
  - Qualities of an operator
  - Role “Definition”
  - Team transition from design/testing to operations
- Operations Rhythm
  - Planning
  - Staffing
  - Procedures



# Team Design

# Operator Qualities

- Trust in team / trust in process
- Honesty
  - Disclosure of mistakes
- Situational awareness
- Ability to document
- “Firefighter” workload
  - Handle unpredictable cadence of boredom and high pressure
- Punctuality

The primary collective responsibility is **to protect the spacecraft from harm.**

# Recommended Roles - Operators

## Flight Directors (FD)

- Lead pre-contact & post-contact “pow-wows”
- Lead shift hand-off
- Maintain MOC discipline (e.g. noise, crowding, distractions)
- Call in back-up in event of an anomaly
- Monitor crew health & safety (e.g. crew exhaustion)

## Operations Engineers (OE)

- Execute day-to-day vehicle activities
- Review current Shift Plan at start of shift, & maintain Contact Logs throughout shift
- Review and uplink command sequences
- Monitor real-time spacecraft state-of-health for anomalous behavior

# Recommended Roles - Planners

## Mission Planners (MP)

- Generate follow-on Shift Plans based on Weekly Plan & outcomes of current Shift Plan
- Generate time-tagged command sequences as-needed
- Maintain and plan around vehicle constraints
- Schedule contacts

## Payload Lead (PL)

- Manages experiment coordination
- Holds ownership of Experiment Plan
- SME for payload subsystem

# Other Roles

## **Principal Investigator**

- Retains ultimate authority if adjudication is needed
- Retains authority to formally accept risks, such as exiting LEops
- Certifies operations team

## **Operations Lead**

- Organize & lead the Operations Readiness Campaign
- Organize & lead the nominal cadence of on-orbit operations
- Primary author for Weekly Plan, collaboratively written at Weekly Planning Meeting
- Define & implement operations processes

## **Program Manager**

- Managing operations resources (facilities, funding, personnel)
- Managing operations policy approvals
- Stakeholder engagement & reporting
- Contribute to Weekly Plan at Weekly Planning Meeting

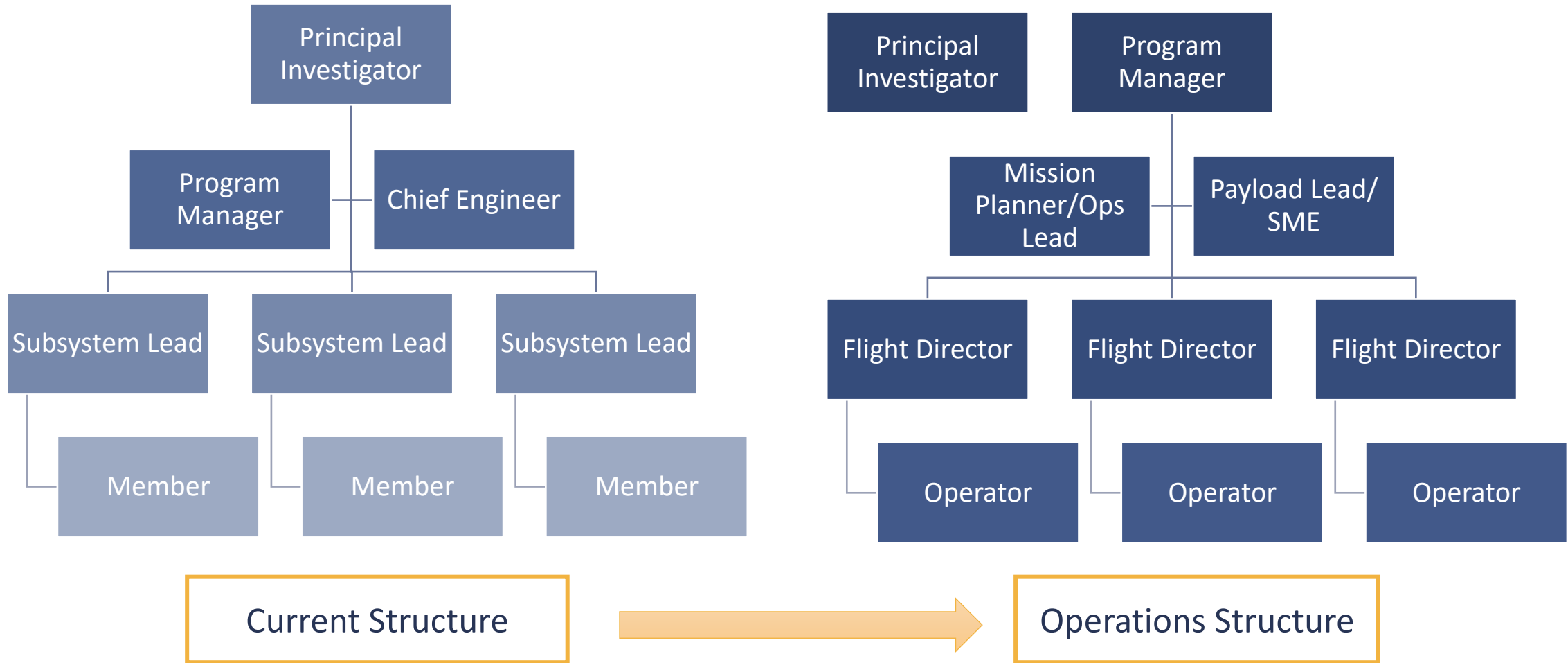
## **Subject Matter Expert (SME)**

- Technical lead during the on-orbit mission
- Technical lead of anomaly resolution teams
- Contribute to Weekly Plan at Weekly Planning Meeting

## **Ground Team**

- Maintaining ground system infrastructure
- Maintaining MOC IT infrastructure

# Potential Transition in Operations





# Potential Transition in Operations

## Operations Team

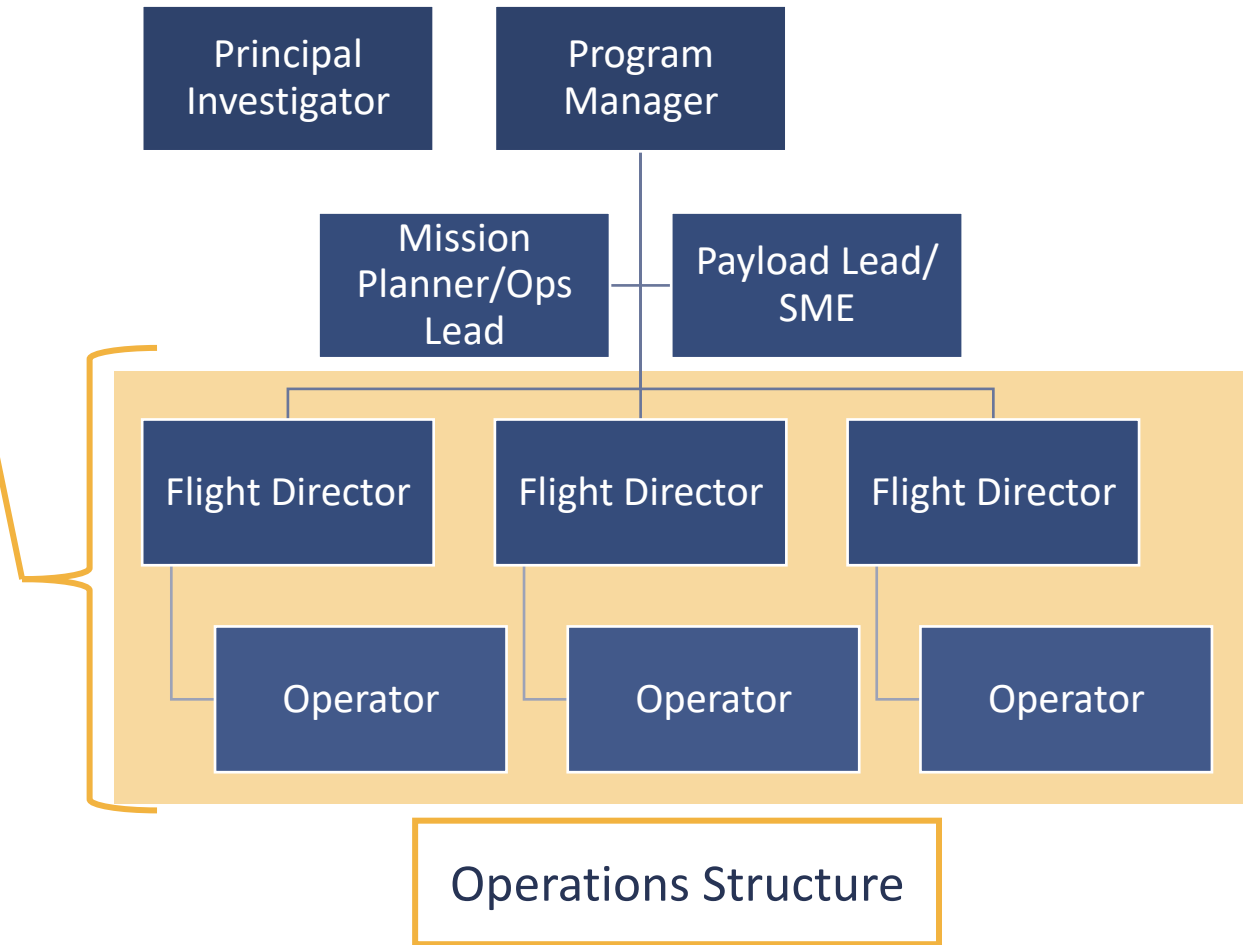
- Command and Control
- Anomaly Response
- Monitoring State of Health (SOH)

## Program Management Team

- Mission Objectives
- Long-term planning
- Experiment analysis

## Both Teams

- Anomaly resolution
- Short-term planning



# Potential Transition in Operations

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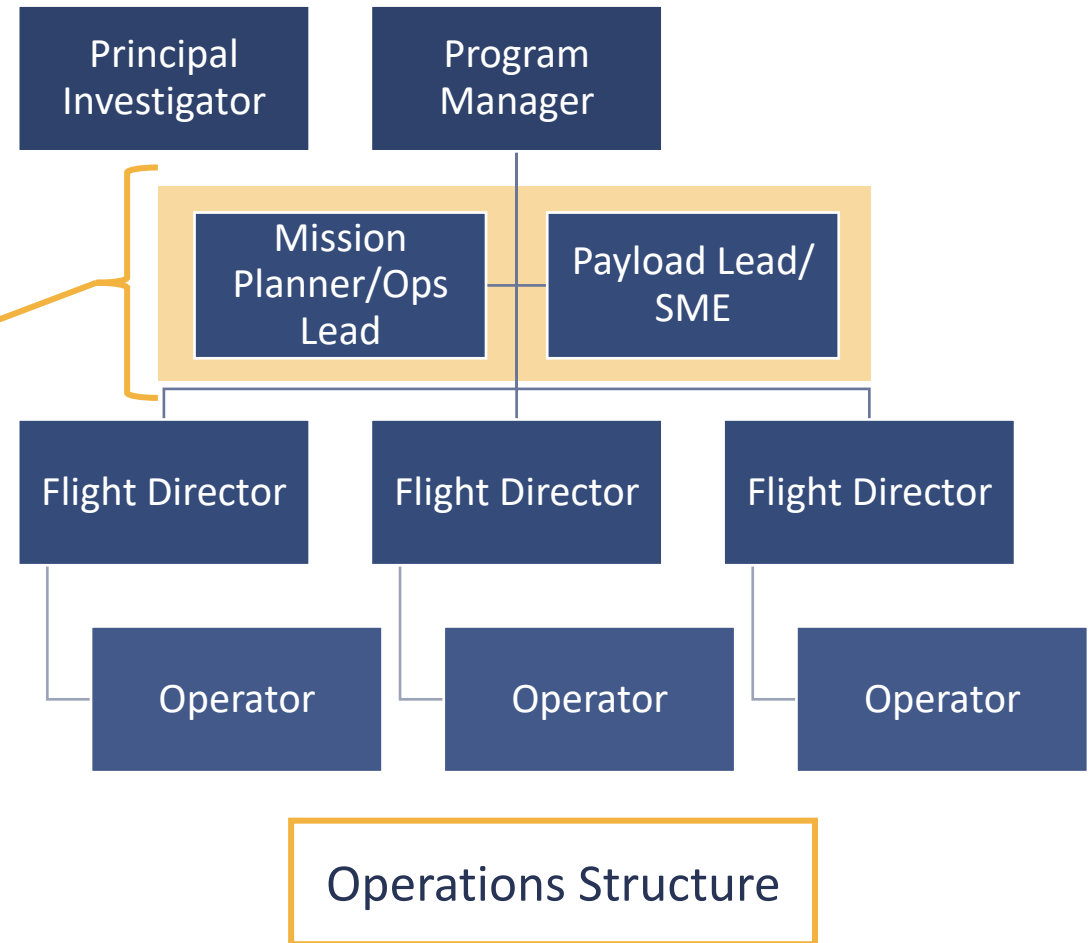
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# Potential Transition in Operations

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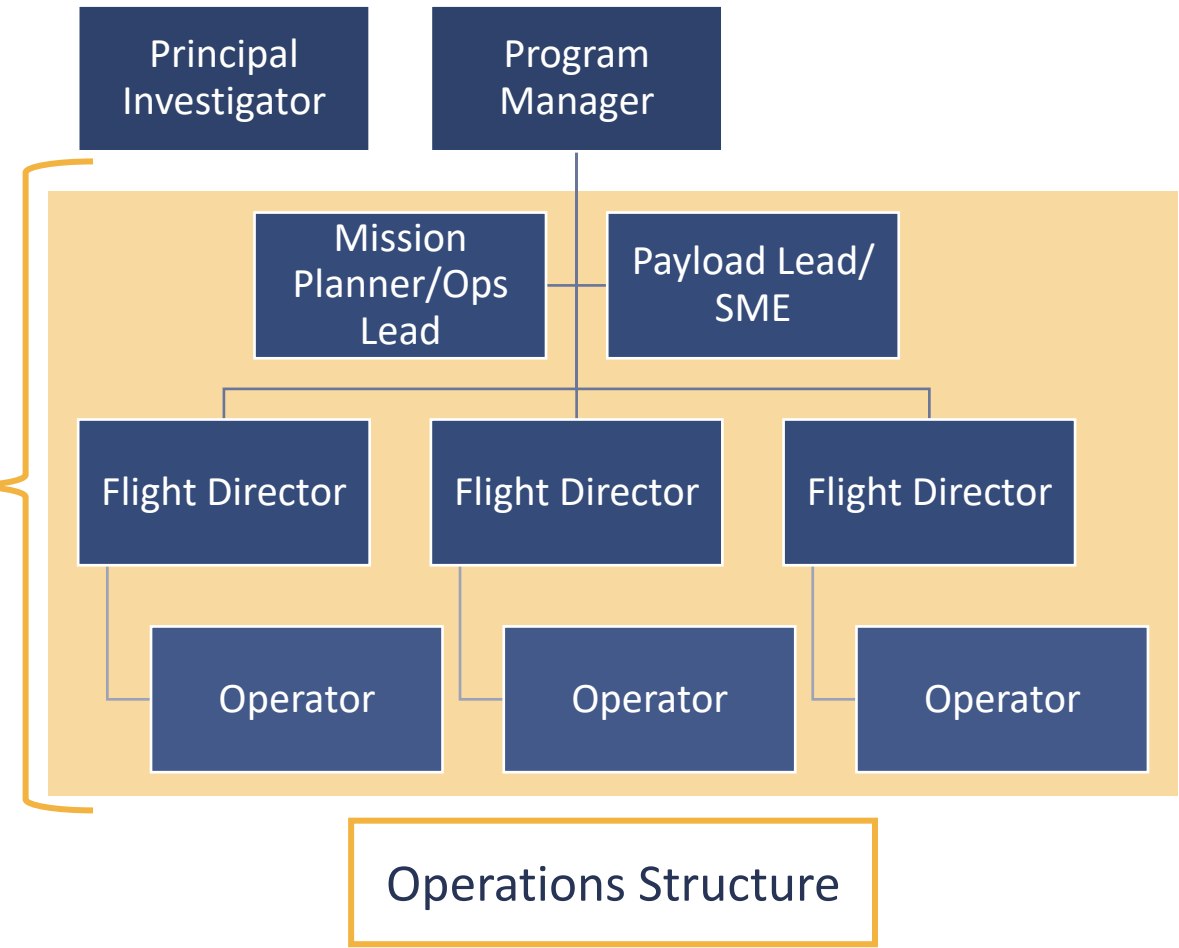
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# Role Organization – Additional Example



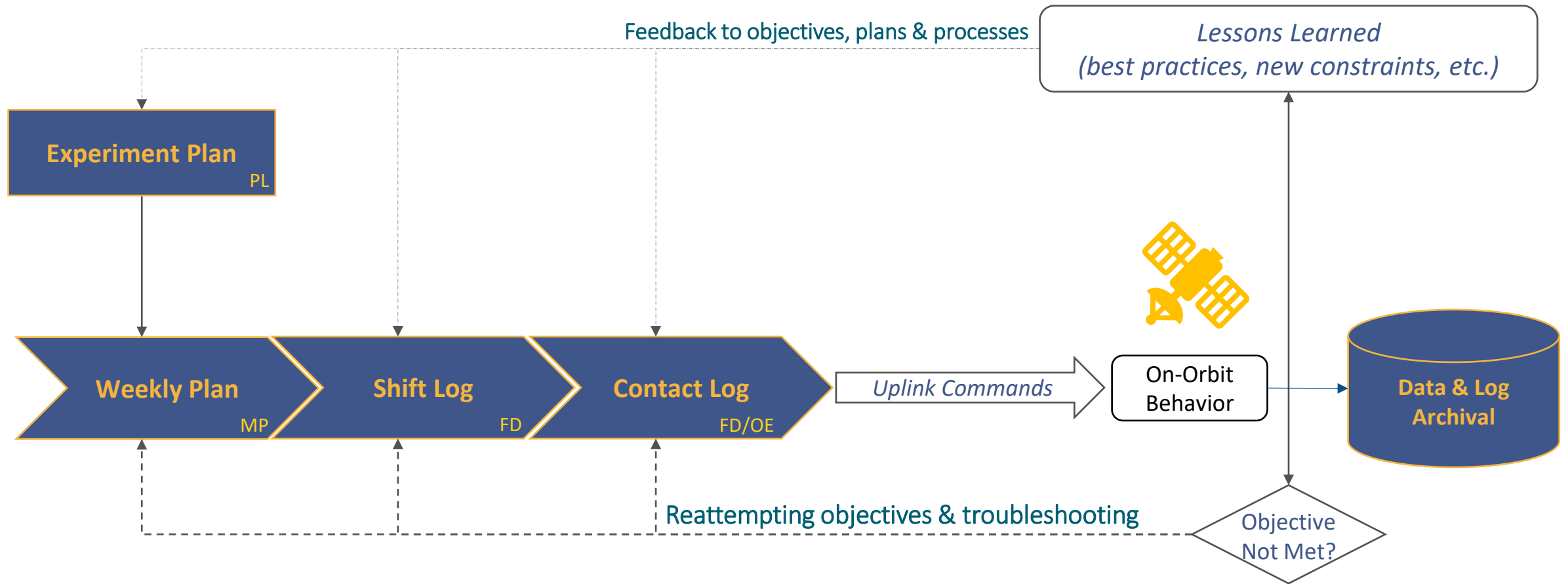
## Things to keep in mind:

- You can have multiple hats, but you can only wear one at a time
- Approvals are 2-person, not 2-role
- Well defined roles that spread responsibility among team members
- Double check EVERYTHING!



# Operations Rhythm

# Operations Rhythm



# Operations Rhythm Planning

## Plan Change Procedure

- Plan changes must be approved by the owner and an appropriate MP or SME
  - This applies to ad-hoc changes on the floor proposed by a SME. FD must give verbal approval before an OE can execute
- Log all changes and test/verify as necessary

## Experiment Plan

- Owned by Payload Lead

## Weekly Plan

- Owned/ developed by Mission Planning Team, used as template for FD/OE to make Daily Plans

## Shift Log

- FD owns the plan for their shift and the next based on Weekly Plan directives. (Plans farther out are owned by the MP team)
  - Gives the FD the authority to modify objectives for the next shift based on what does or doesn't happen on their shift

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	Ground Contacts scheduled	MP team develops next week's plan				

# Operations Rhythm Shift Log

- Who is on shift?
- When did each pass start and end?
- Shift conclusion
- What happened during the pass?
  - What order were commands sent?
  - Did something abnormal happen?
- Shift conclusion
  - How was the full shift?
  - Did any events occur?
  - What should next shift pick up with?

## Example Log:

**Page properties**

Students On Shift/ Present	
Shift Start Time (Time Zone)	
Shift End Time (Time Zone)	

---

Pass

Pass 1 (Time Pass Started - Time Pass Ended):

Plan:

Log:

---

**Page properties**

Shift Conclusion

Summary

*How was your shift? Did any events occur:*

---

Guidance for next shift

*What should the next shift pick up with?*

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	Ground Contacts scheduled	MP team develops next week's plan				



# Operations Rhythm Staffing

## Items to think about

- How many shifts are students allowed to have per week?
  - How does the team not burn out?
  - Can a student have multiple shifts in a row?
  - How does scheduling work?
- Will there be someone on-call?
- Who creates the schedule for the day/ week/ month?
  - How does class schedules impact your operations?
  - What is the process for someone to call in sick?

## Example staffing rules

- FD/OE staffing limits
  - No more than 5 shifts per week
  - No more than 3 grave shifts in a row\*
    - \*Payload ops is an exception – no more than 5 shifts every three weeks
  - At least 24 full hours of rest when switching shift time slots
- All positions will have someone on call at all times
- Ops Lead handles crew scheduling

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
				OL publishes schedule for next week, draft for two weeks out		

# Operations Rhythm Staffing

## Questions to ask:

- Have criteria gates for how staffing changes will occur across the life of the mission
- How stable is the vehicle?
- How many operators do you have?
- How long is the mission life?

# Operations Rhythm Staffing

## LEOPS Staffing

- Largest group

## Nominal Ops Staffing

- Down selected to smaller team

## Reserve Staffing

- Attendance for awareness/learning
- Staffing to be reassess later in nominal operations

## 6+ months of Nominal Ops

- Refresher training potential  
turnover of students

- Having a plan for LEOPs
  - High demand / all hands on deck
- Nominal Operations
  - Busy but less stressful conditions
    - Can we add more members to the team?
    - Do we need to have as many passes?
    - Will we meet our mission objectives with current pace?
    - Is anyone getting burnt out?
    - Do we have enough trained operators?
    - Can we improve our CONOPS or tools?

# Operations Rhythm Staffing - Example

- **Staffing Phases and Entrance Criteria**
  - 24-Hr Staffing
    - Start here, minimum 72 hours
- **16-Hr Staffing**
  - Notification of anomalous behavior
  - Completion of initial SOH checkout
- **8-Hr Staffing**
  - Completion of GNC verification
  - 10 days without mission-endangering anomaly
  - Demonstration of out-of-pass planning with automated pass handling, aka cross-pass automation (OE observation only)
- **No Weekend Staffing**
  - Reliable 2-day ground-only pass handling
  - Cross-pass automation

# LEOps to Experiment Operations - Example

## Staffing Rhythm

- PL responsible for weekly crew scheduling
- **LEOps**
  - 3x 8-hour shifts
    - Day (0600-1400)
    - Swing (1400-2200)
    - Graves (2200-0600)
  - Gradually removing graves, swings, and weekends
  - ~4 weeks duration
- **Nominal Ops**
  - 1x 8-hour shift: Day (1000 - 1800)
  - On call shift for evening/night
- **Experiment Ops**
  - Additional certification/training
  - Select passes to match orbit
  - Payload passes will be staffed in addition to days

## Planning Rhythm

- MP team: PM, SMEs, OL
- **LEOps**
  - Plan daily, roll back to weekly Nominal Ops cadence
- **Nominal Ops**
  - Weekly planning
- **Experiment Ops**
  - Coordination with required ground station(s)





# Satellite Operations 101

Part Two



# Agenda



- Flight Rules
  - Procedures/Processes
  - Training
- Anomaly Management
  - What is an anomaly?
  - Mitigation
  - Resolution





# Flight Rules

“EAT 2”

# Procedures

- **Procedures include guides, as-runs, and scripts**
  - Already tested/developed by SMEs, MPs, approved for use by operations team
- **Special Commanding**
  - Must be approved by both SME and FD
  - Test on flatsat where possible
  - Repeatable Special Commanding will be turned into pre-built procedures
- **Leadership can veto any commanding if deemed too risky**
- **Risky objectives should have a tested procedures associated with them**
  - How to reset your satellite
  - How to change modes
  - How to recover a random reset
  - How to complete an action for the first time
    - I.e. deployments, different experimental modes, contact, etc.

# Operations Best Practices



- Formality is adaptable
  - Maintain active communication and awareness
    - Take notes in a shared space
  - Two-person verbal check, at least one FD approval
  - Pre-pass and post-pass meetings
    - Fluid formality – just be sure to check in
  - Elevate formality as needed
- Cowboy Commanding: commanding off-the-cuff without proper approvals
  - Yes, it's faster. No, don't do it. It can cause “anomaly snowballs.” We don't want cowboys trapped in snowballs.



# Operations Best Practices

- **Expect...**
  - The unexpected, space craft personalities
  - Anomalies
  - A constant learning process for all parts of ops
  - A delightful mix of boredom and chaos
- **Make best use of all contact time**
- **Everything on the operations floor ultimately goes through the FD**
- **Keep a cool head on console – no cowboy snowballs!**

# Certification - Recommendations

- Operators will be required to regularly staff shifts
  - No shift for 30 days – on Reserve until shadow 1 shift, attend refresher brief with Ops team
  - No shift for 2 months – on Reserve until shadow 2 shifts, attend short lecture retraining series
  - Shadow shifts: on-duty FD/OE should actively teach/refresh shadow-er
- Members are responsible for finding their replacements if they need to cancel a shift
  - No Shows (miss shift) – on Reserve until shadow 1 shift, attend refresher brief with Ops team
    - 2 “strikes” before being decertified

# Training Ideas

# Training - Recommendations

- How closely can you mimic the real thing?
  - Flatsat, sim, white card, previous mission?
- Operators will likely be first timers
  - Start with the basics what simple everyday tasks will need to be accomplished
    - Check the last shifts log, battery voltage, weekly plan etc.
  - Progressive difficulty
    - More difficult but regular tasks
    - LEOPS & Anomalies
- Who is the A-team?
  - Any standouts? Previous experience? Vehicle knowledge?

# Anomaly Management



# What is an Anomaly?

- Something that deviates from what is normal/standard/expected
- Can be on the vehicle or ground
- Most likely human-induced
- Known/previously seen anomalies should have documented response(s) to run through
- Planning/commanding errors should be resolved by halting activities, safe vehicle if necessary, re-planning

# Anomaly Factors and Risk Mitigation

- Factors
  - (gasp) humans
    - Avoid fatigue where possible
    - Keep up to date on training and awareness
    - Communicate with your team
  - Sometimes the bus or part(s) of the ground chain are problems too
    - But mostly it's humans
- Risk Mitigation
  - Flight rules
  - Clear documentation, procedures, etc.
  - Command in least risky order

# Potential Satellite/Ground Anomalies

- Negative acquisition
- Command timeouts (24hr, 48hr)
- Bus Reset
- Battery undervoltage
- Safe Mode (technically an anomaly symptom/indicator)
- Tumble
- Component degradation/loss
- Space weather
- Planning/commanding errors
  - Mistyped parameters, commands missing from plans, violating orbit/mode constraints, improper activity

# Handling Anomalies

## Determine vehicle state

- Can run Blind Acq, Reset Recovery

### 1. Safe the vehicle

### 2. Get more pass time\*

- \*beware power issues

### 3. **Gather the experts**

- FD and OE make calls
- Go for on-call SME first
- Can call LFD/OL for advice/support

### 4. Gather data

- Telemetry, plans, external factors
- **Timeline!**

### 5. Report up the leadership chain

- Get some info first, but – tell someone

### 6. Anomaly Meeting

- Only once vehicle is safe/out of contact

### 7. Develop and implement solution

- Test on ground
- FD has final yes/no for implementation
- Document everything!

### 8. Repeat as necessary

# Anomaly Resolution

## Anomaly resolution tips to keep in mind

- Multiple root causes are possible – look for past human error
- Be mindful of stress/odd hours/quick turnaround impact on human error
  - Maintain two-person verification of all commands
  - Remember everyone on the team has homework, tests, and grades to worry about
- Leverage the expertise of the team, but keep everyone as rested as possible
- Document everything
- Designate someone to communicate outside the ops floor (esp. to leadership)
- No cowboy snowballs!

## Things you can check for when looking for human error:

- Uploaded commands
  - Are there any incomplete on/off pairs?
  - Did any sequencing produce an anomalous state?
- Command history
- Verify against the Daily Plans
- Typos in commands

