FLIGHT OPERATIONS DIRECTORATE

FLIGHT DYNAMICS DIVISION

Rendezvous Pointing and Software Branch

Visiting Vehicle Operations Office

From Where did the Visiting Vehicle Requirements Come

9/24/15

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Two Elements

- **Vehicle Design Requirements**
- **Vehicle Operations Implementation**

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Early NASA Programs

- ISS Freedom first proposed in 1984
- To be built using Space Shuttle
  - Crew transfer
  - Cargo resupply
  - Manual piloting for proximity operations
  - Launch/Entry
  - Provided rendezvous experience for ground operators and crew
- Orbital Maneuvering Vehicle (OMV) to provide unmanned cargo support
  - Cargo resupply
  - Automated and remote piloting rendezvous
  - Requirements developed but vehicle not flown
- Demonstration Programs in Early 1990's also produced a significant requirement set
  - Man Tended Free Flyer (MTFF)
  - Automated Rendezvous and Capture Project (AR&C); NASA and ESA
    - ARP Kernel – ESA flew rendezvous sensors on Shuttle
  - Others

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ISS Reborn

- Phase One Program was a NASA/RSA joint effort
  - US astronauts flew to Mir
  - Russian Cosmonauts flew in the Space Shuttle
  - Some Joint operations concepts were proved
- Mid 1990's
  - ESA and JAXA proposed building resupply vehicles for ISS
    - Requirements for these vehicles were developed using requirements from earlier programs and expertise from flight history
  - Visiting Vehicle Interface Definition Document (VV IDD) developed
  - Approach Ellipsoid concept
    - Allows partners flexibility in designing the approach and departure trajectories
    - Draws clear lines to assess safety margins

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Approach Ellipsoid Philosophy

- Considerations
  - Safety – Collision is the dominate risk
  - Two modes of flight: burn targeting and forced motion
  - Sensor transitions
    - Range and Range Rate are dominate parameters
  - Timeline management

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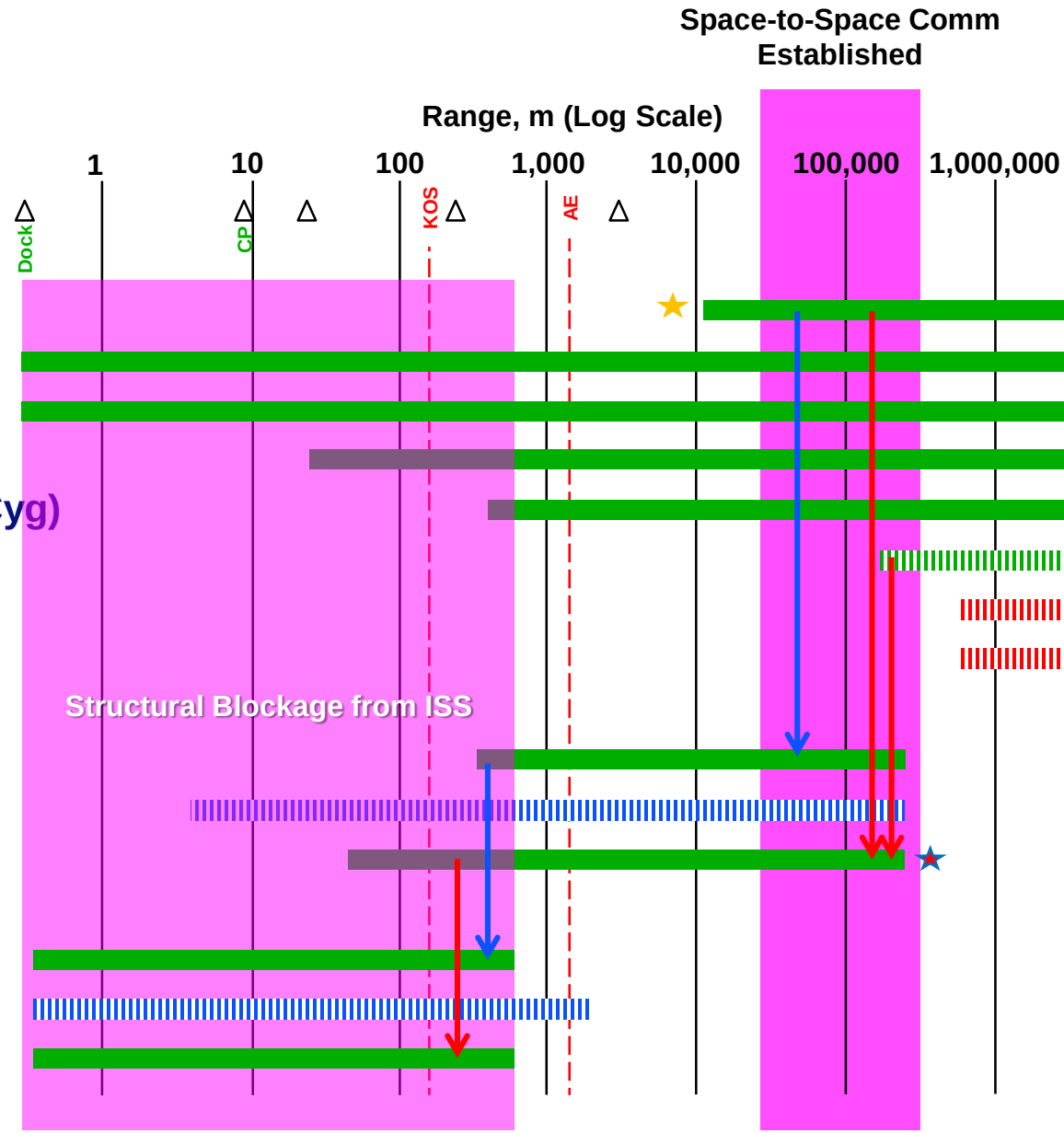
Range of Utilization

- Typical HOLD Points
- Inertial Navigation
  - GPS/GLONASS (P/V)
  - Accelerometer (ΔV)
  - Gyroscope (ΔATT)
  - Earth Sensor (ATT-HTV)
  - Star Tracker (ATT-ATV, Dgn, Cyg)
  - Horizon Sensor (ATT-RS)
  - Magnetometer (ATT-Cyg)
  - Solar Sensor (ATT-RS)
- Far Field Navigation
  - RGPS (P/V)
  - Comm Ranging (R/Rd-HTV)
  - Radio Ranging (P/V; ATT-RS)
- Near Field Navigation
  - Laser/Video Imager (P/V)
  - Thermal Imager (SpX)
  - Radio Ranging (P/V; ATT-RS)



★ Accuracy no longer supports burn targeting

★ Note that ground tracking is also used prior to this range for Russian vehicles

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Approach Ellipsoid Philosophy (cont.)

- Elements
  - Off-set targeting in rendezvous phase
  - 24 hour safe trajectory
  - Corridors that defined safe analyzed space
  - Clear transition of authority

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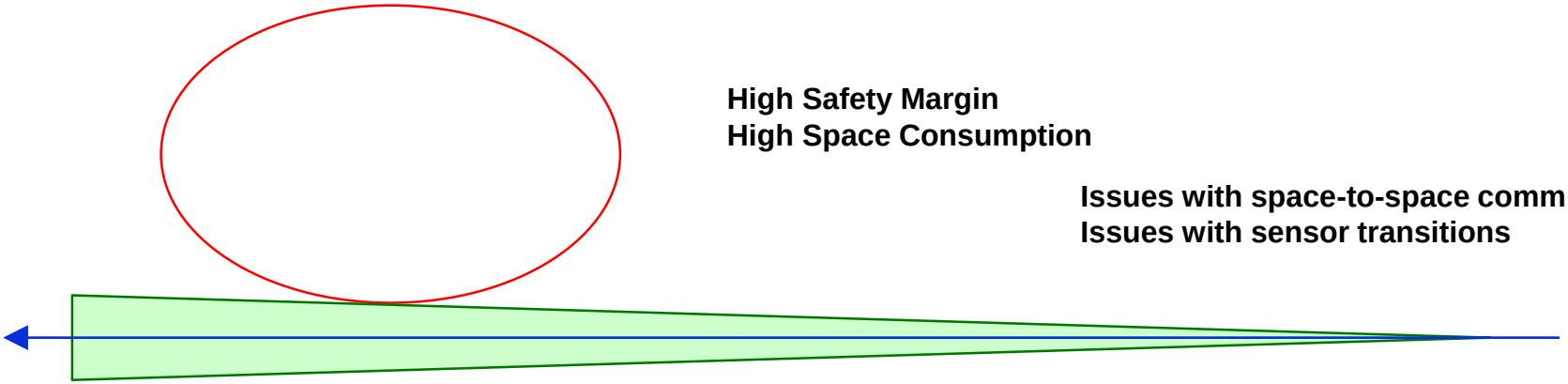
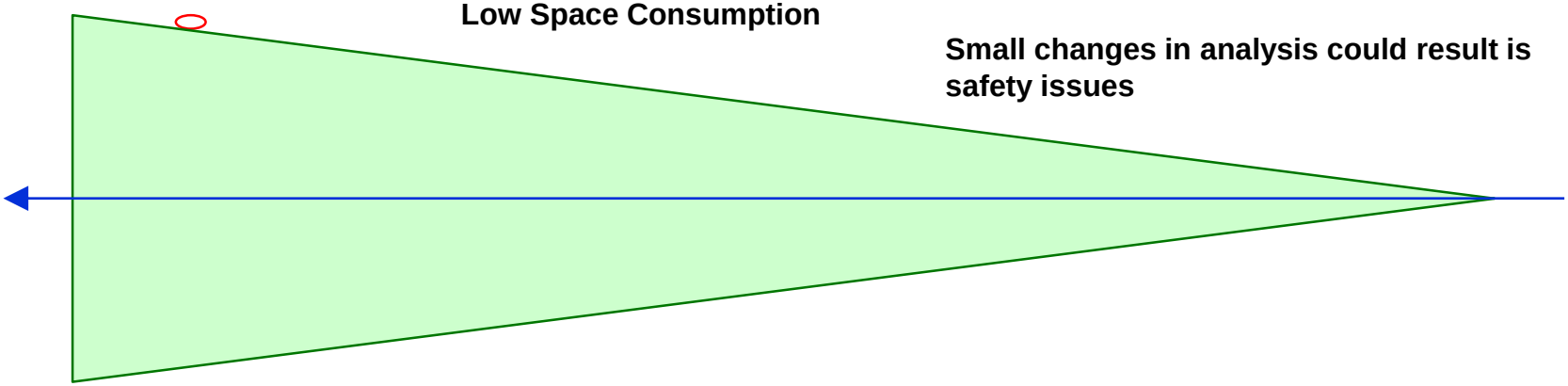
Approach Ellipsoid Philosophy

Size vs Margin



High Safety Margin
High Space Consumption

Issues with space-to-space comm range
Issues with sensor transitions



Low Safety Margin
Low Space Consumption

Small changes in analysis could result is safety issues

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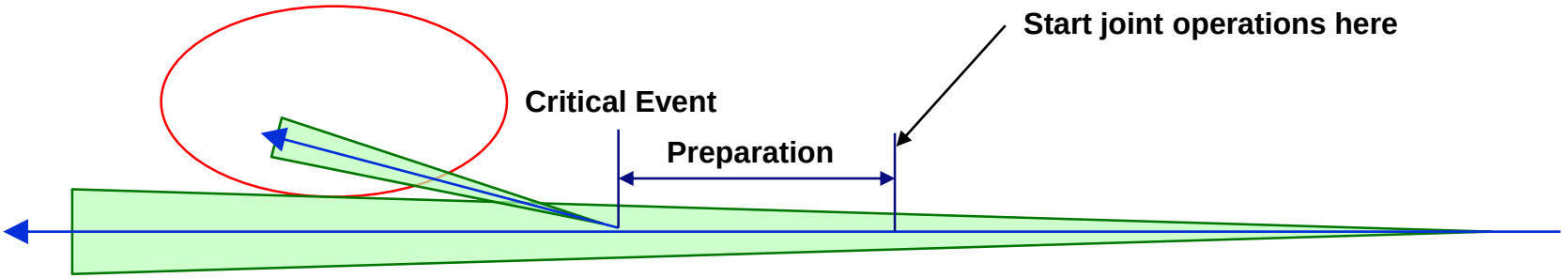
Approach Ellipsoid Philosophy

Who's in charge

At some point the command structure must be unified
When to you change operational mode?



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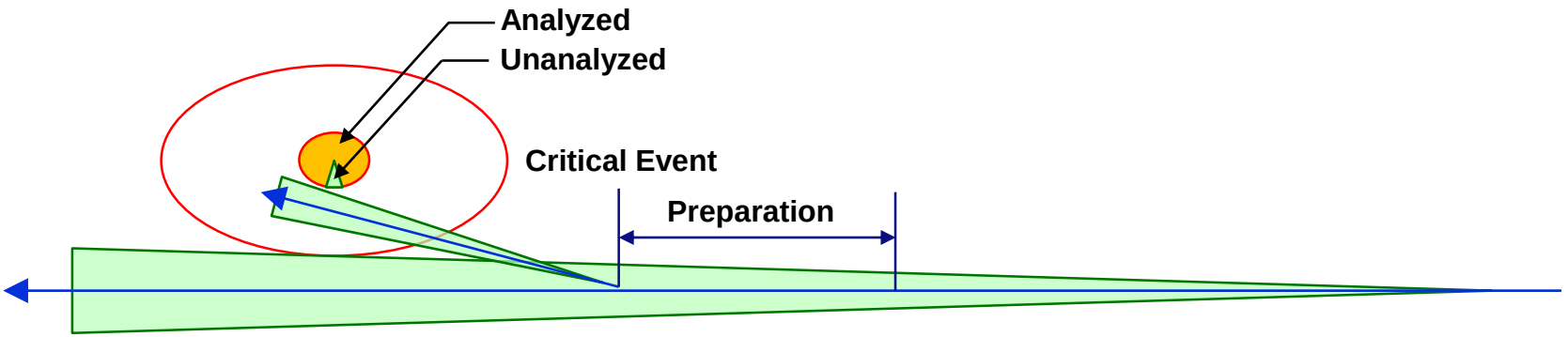
Approach Ellipsoid Philosophy

Only analyze what you need



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Requirements Most Discussed

- Secondary range and range rate
- Crew monitoring

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Operations Problem Statement

- VV operation are complex and the operations team needs to prepare
  - Rendezvous/Prox Ops/Grapple are skills that need to be developed
  - Distributed operations complicate mission execution
  - First flight of the VV will have additional challenges
    - Unproven vehicle systems
    - Unproven operations team
- 1994 ISS Program & MOD decided to allow Visiting Vehicles to operate from their own control centers
- ~1996 ISS Program decided to allow the Visiting Vehicles to fly to the ISS on the first flight
  - Demonstration of vehicle in incremental steps
- Joint training is one of the keys to success
  - Training for ground
  - Crew training on the ground and while in orbit
  - Ops experience should be developed

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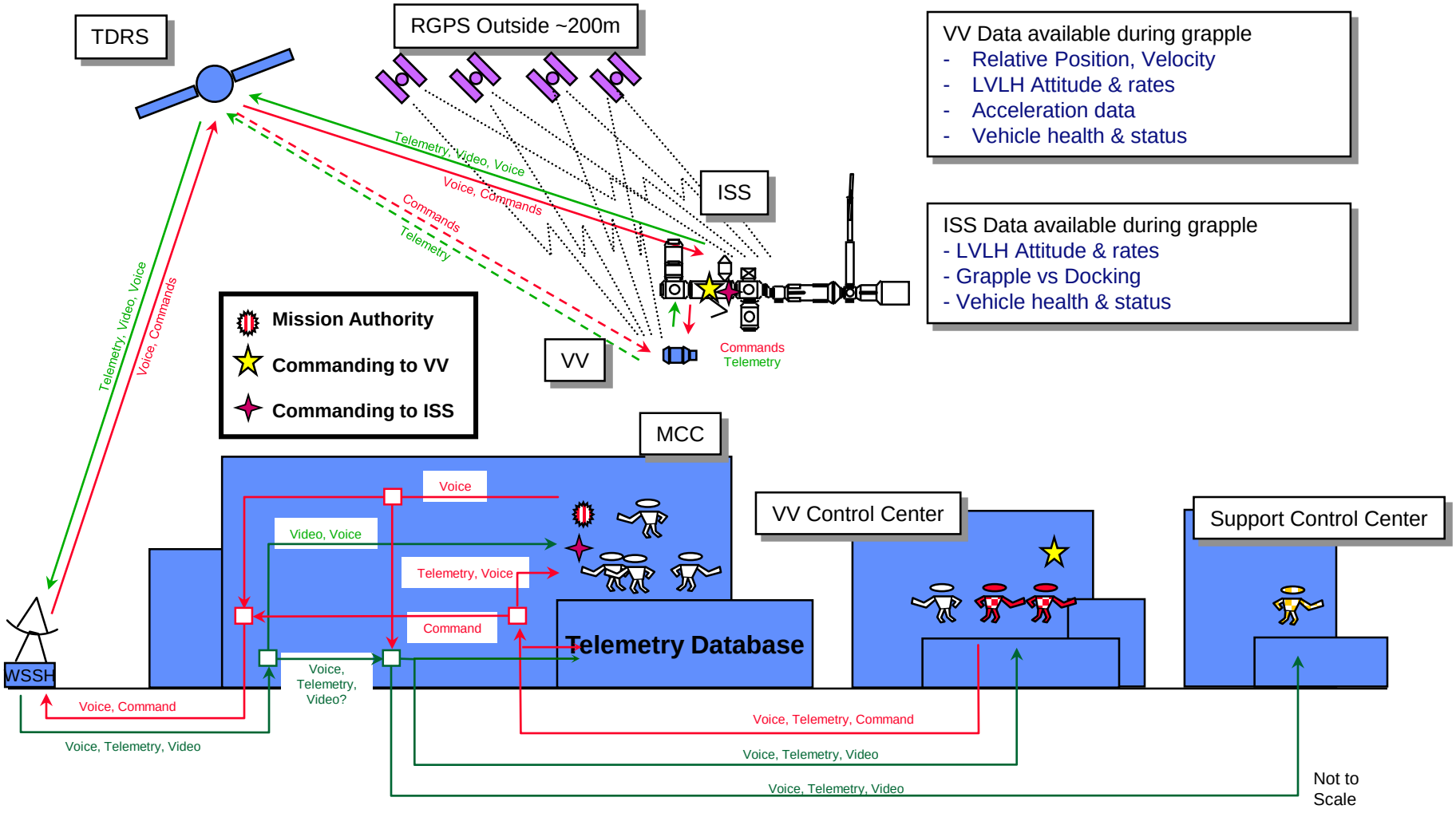
VV Operational Scheme



VV Data available during grapple
- Relative Position, Velocity
- LVLH Attitude & rates
- Acceleration data
- Vehicle health & status

ISS Data available during grapple
- LVLH Attitude & rates
- Grapple vs Docking
- Vehicle health & status

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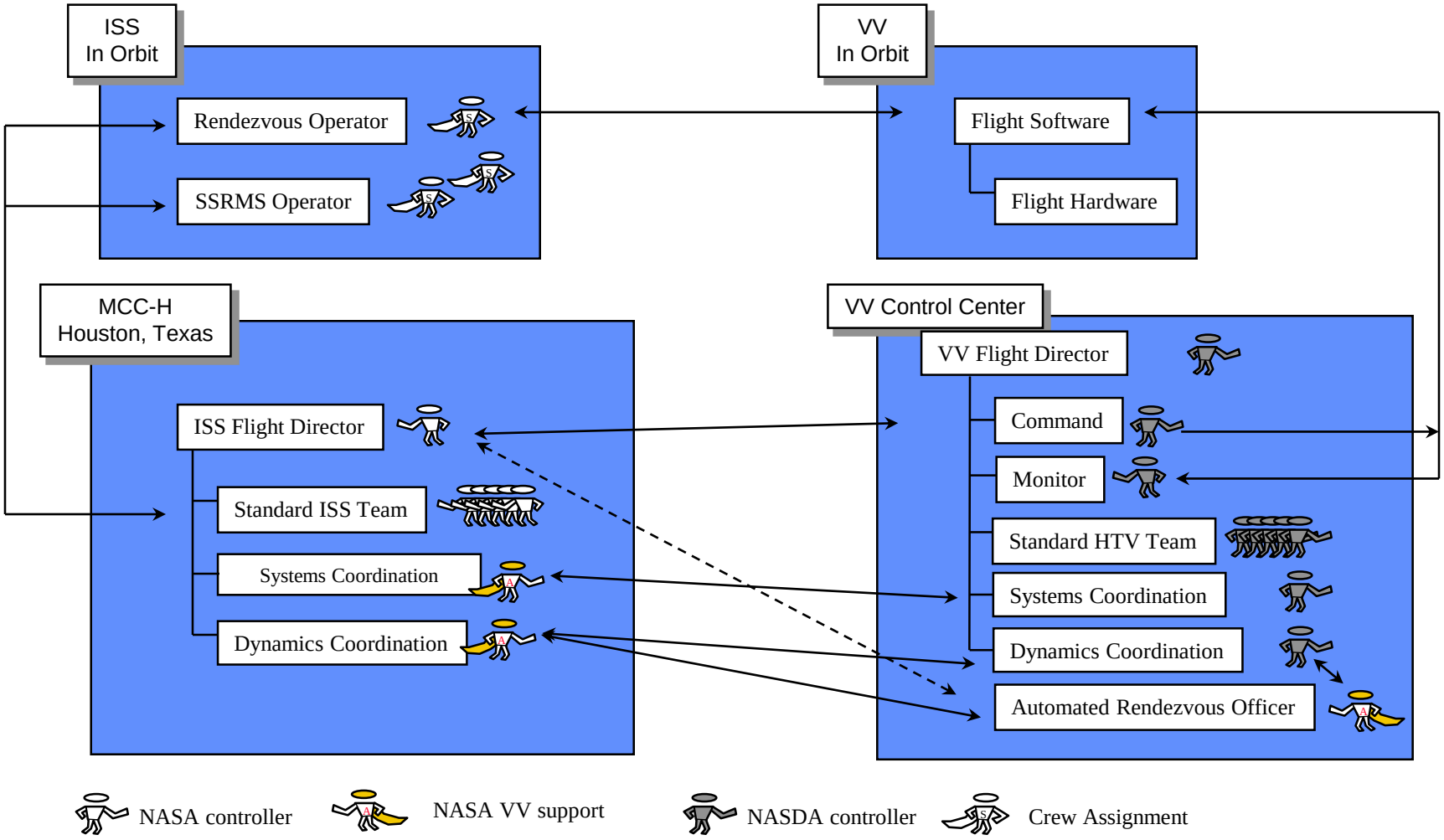
Operations Team Concept



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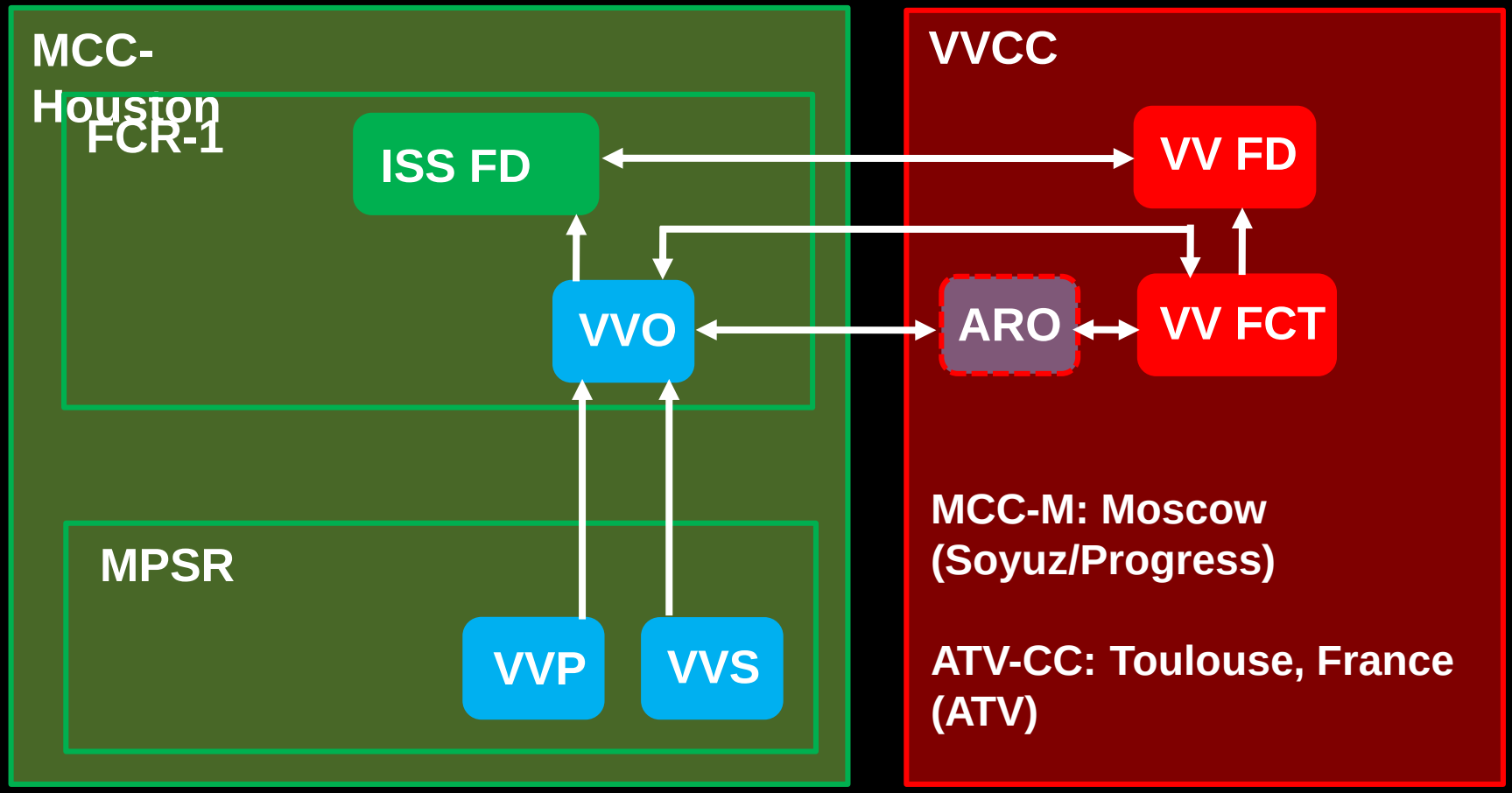
The Visiting Vehicle Team – Docking Vehicles



ARO

- Automated Rendezvous Officer (callsign “Aero”)
- Supports in VV-CC
- Insight to data/voice not available in MCC-H

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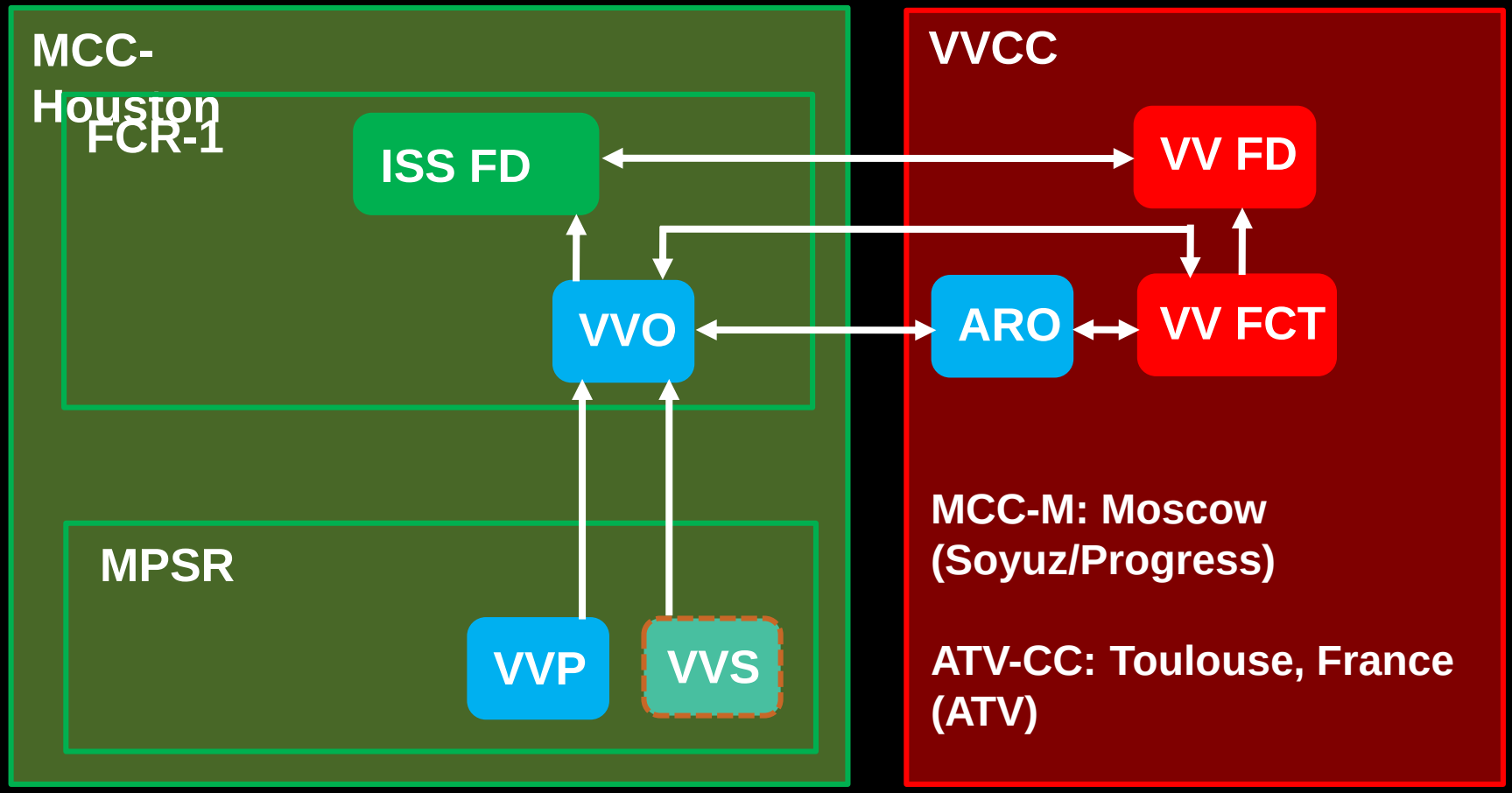
The Visiting Vehicle Team – Docking Vehicles



VVS

- Visiting Vehicle Support (callsign “VV Support”)
- Monitor VV GNC systems performance, flight rules & procedures
- Manage displays and clocks
- Update products/summaries

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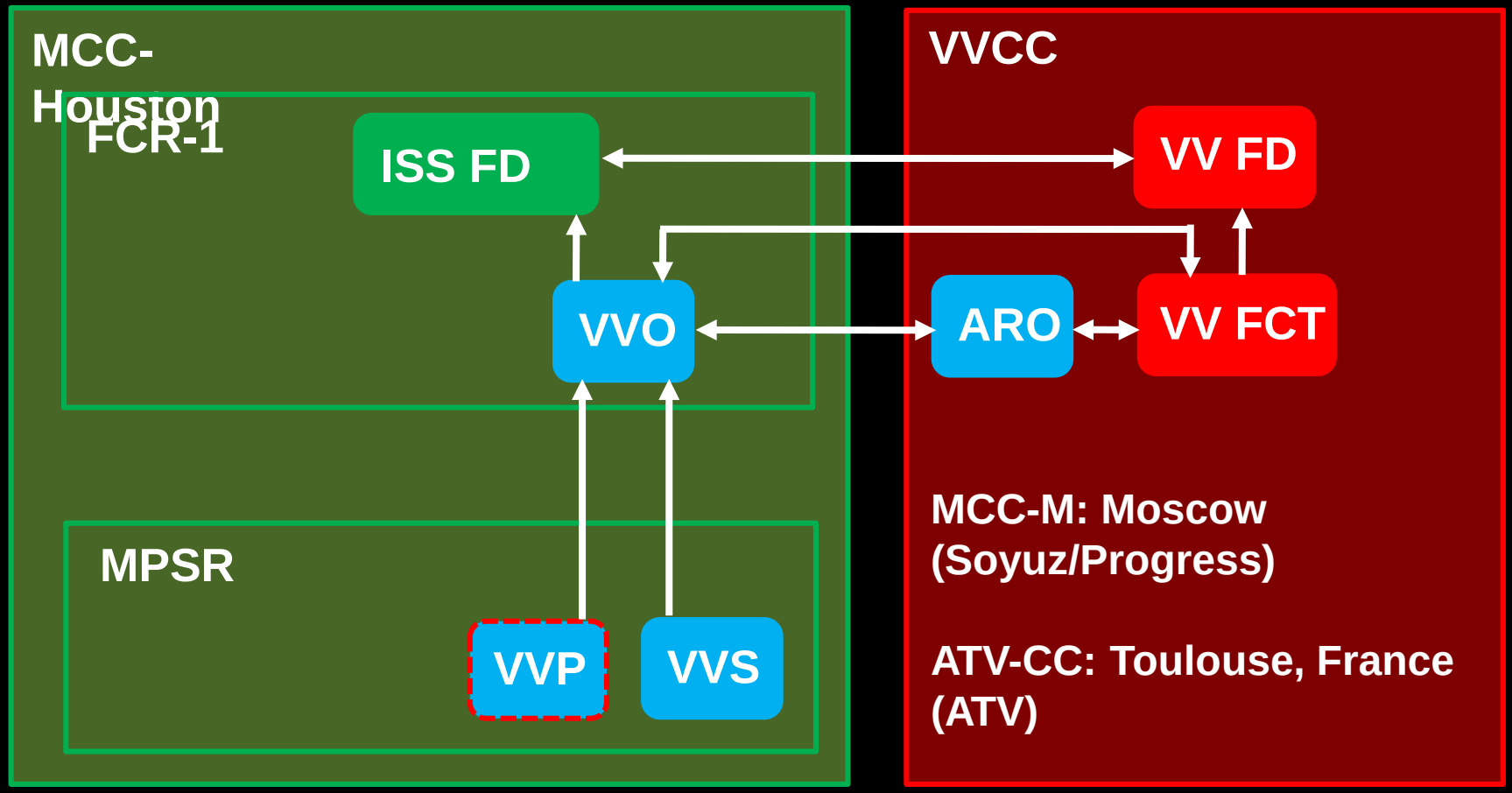
The Visiting Vehicle Team – Docking Vehicles



VVP

- Visiting Vehicle Profile (callsign “VV Profile”)
- Monitor VV trajectory performance
- Perform independent targeting of VV rendezvous burns
- Does not support Soyuz/Progress

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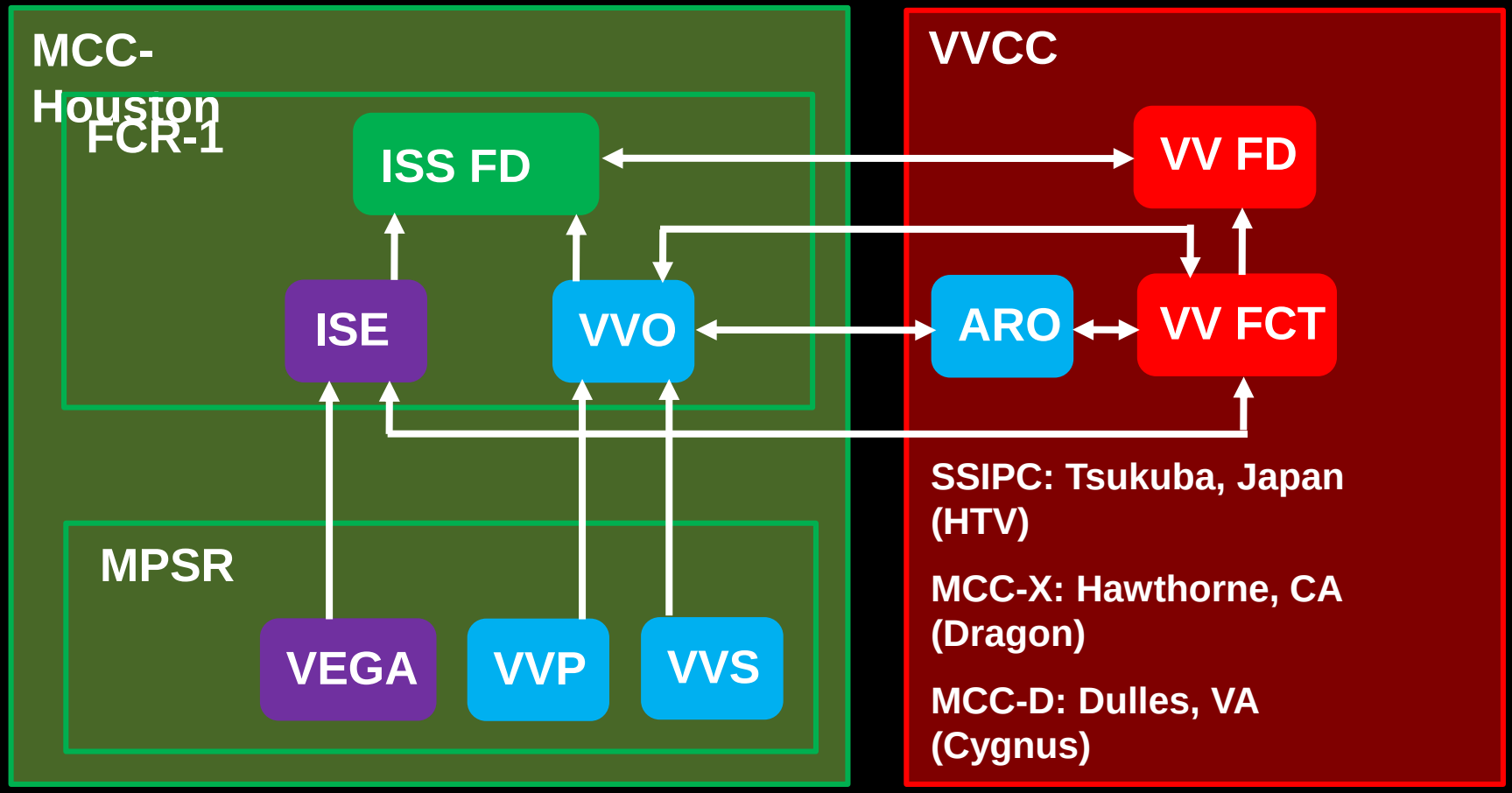
The Visiting Vehicle Team – Grappled Vehicles



ISE

- Integration & Systems Engineer (callsign “Ice”)
- VV systems integration (CO)
- ISS/VV interfaces and VV backup commanding
- MPSR: Vehicle Integrator (“VEGA”)