# The Bandit: An Automated Vision-Navigated Inspector Spacecraft

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# Motivation

- Improvements in spacecraft reliability and operational lifetime require on-orbit inspection and servicing
- Inspection: On-demand images of spacecraft exterior
- Design approach: deployable inspector vehicle
  - Small (tiny, really)
  - Low-cost
  - Safely stowed between sorties
  - Long-lasting (refueled / recharged?)
  - Autonomous

# Agenda

- **Program Overview, Philosophy and Constraints**
- **Bandit Mission Description**
- **Subsystem Details**
- **Prototyping**
- **Conclusion and Future Work**

# Program Overview

- Project Aria at Washington University
  - Joint activity of MAE & CSE departments sponsored by School of Engineering
  - Hands-on student engineering activities in land, air and space robotics
- Flight opportunity:  University Nanosat-3 competition [AFRL/NASA/AIAA sponsorship]
  - 30 kg spacecraft
  - 18” cylinder
  - 2005 delivery date
  - Bandit is one of several candidate payloads

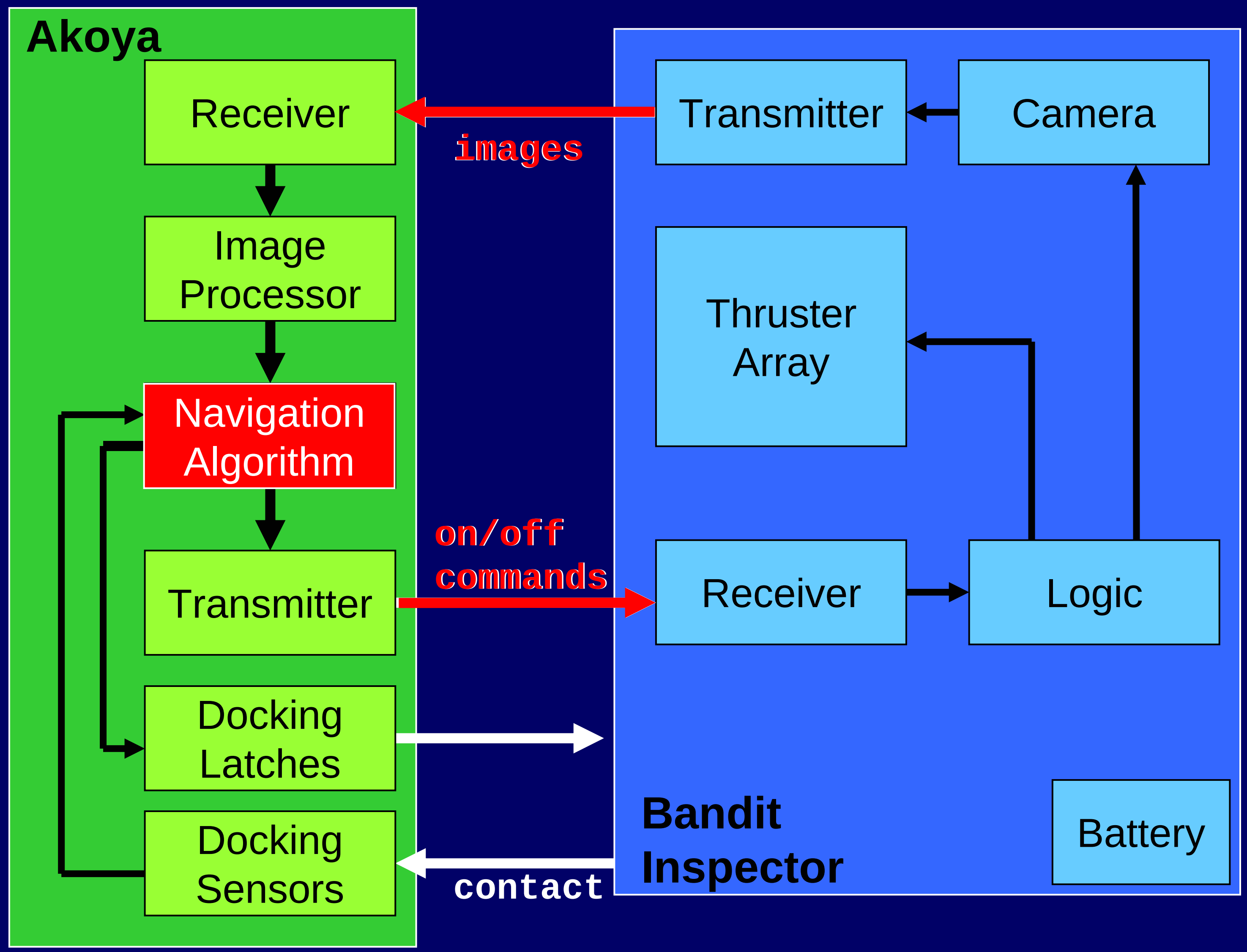
# Project Constraints & Assumptions

- Demonstration of key enabling technologies
  - Ultra-low-cost miniature inspector spacecraft
  - Autonomous, image-based navigation
  - Repeatable docking
  - Close-in maneuvering near parent spacecraft
- Extremely constrained operating conditions
  - 1 kg deployed mass
  - Battery-powered with TBD recharging capabilities
  - No refueling capability
  - Limited data downlink
- Student-focused design project

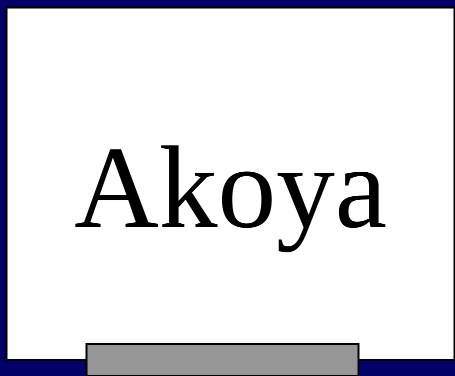
# A Wonderful Tension

- Severe operational constraints force innovative (and risky) designs
- Severe flight safety constraints force thorough consideration and validation
- A great position for students
  - Our products are capable students & research
  - “Design, build, test, launch … fail” is an acceptable mission outcome!
- We accept operational risk (not flight-safety risk)

# Mission Block Diagram

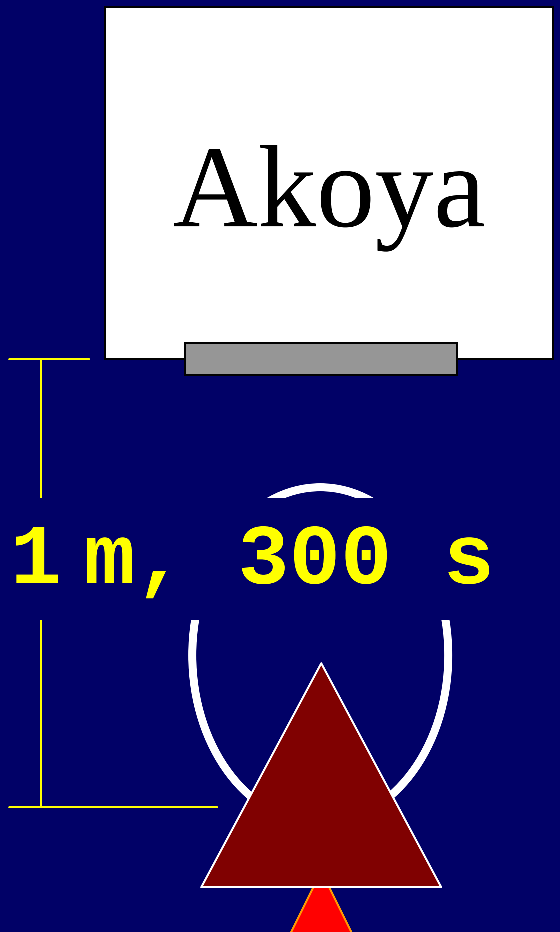


# Bandit Mission Overview




- Incremental demonstration of docking and maneuvers
- Phase 0:  Release-Dock (10 mm/s, 20 seconds)

# Bandit Mission Overview

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- Phase 0: Release-Dock (10 mm/s, 20 seconds)
- Phase 1: Park (18 mm/s, 10-15 minutes)

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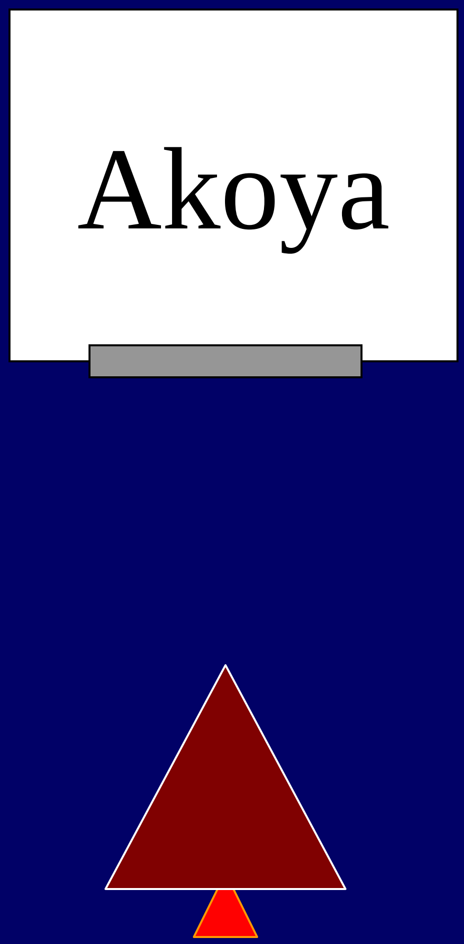
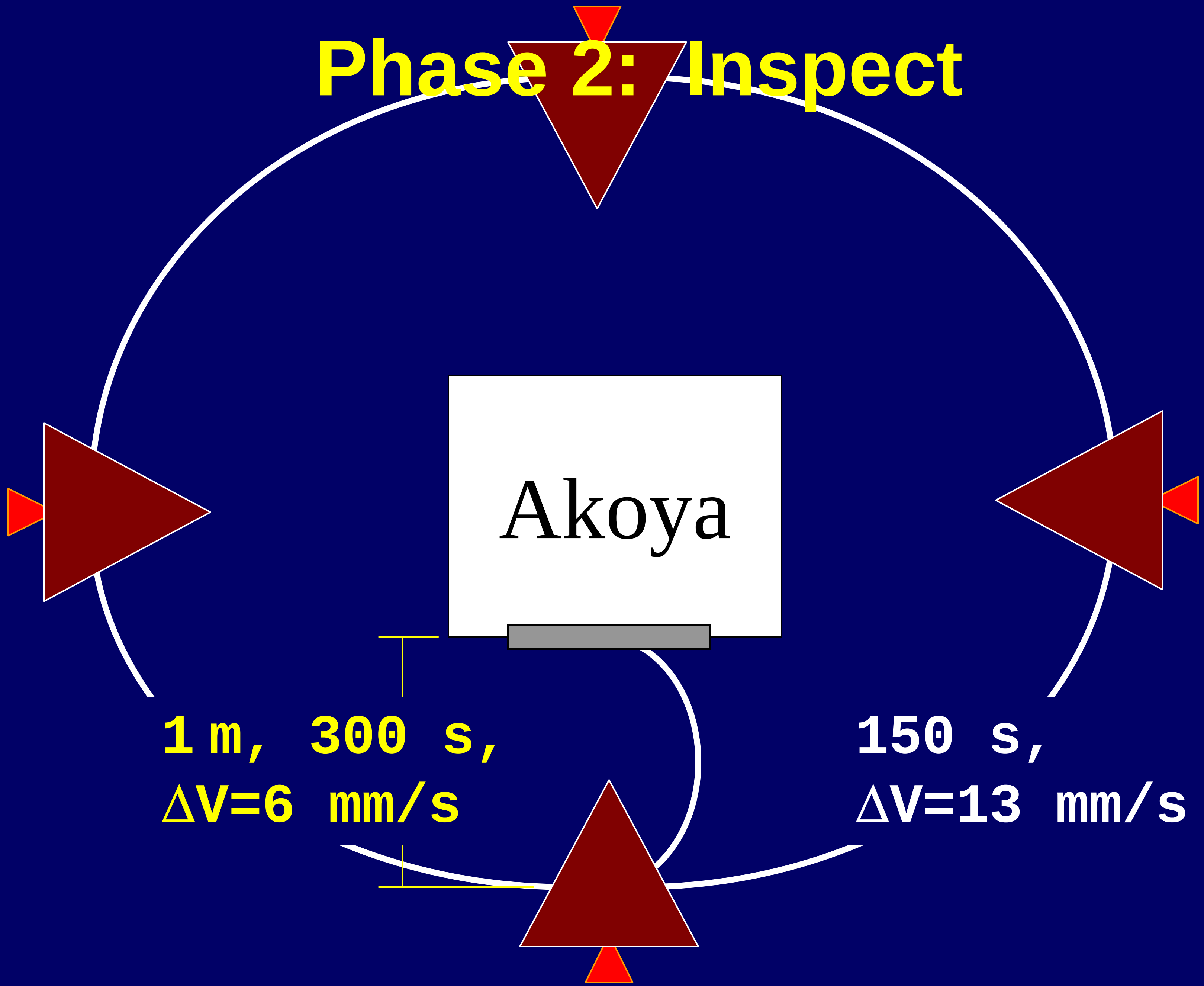
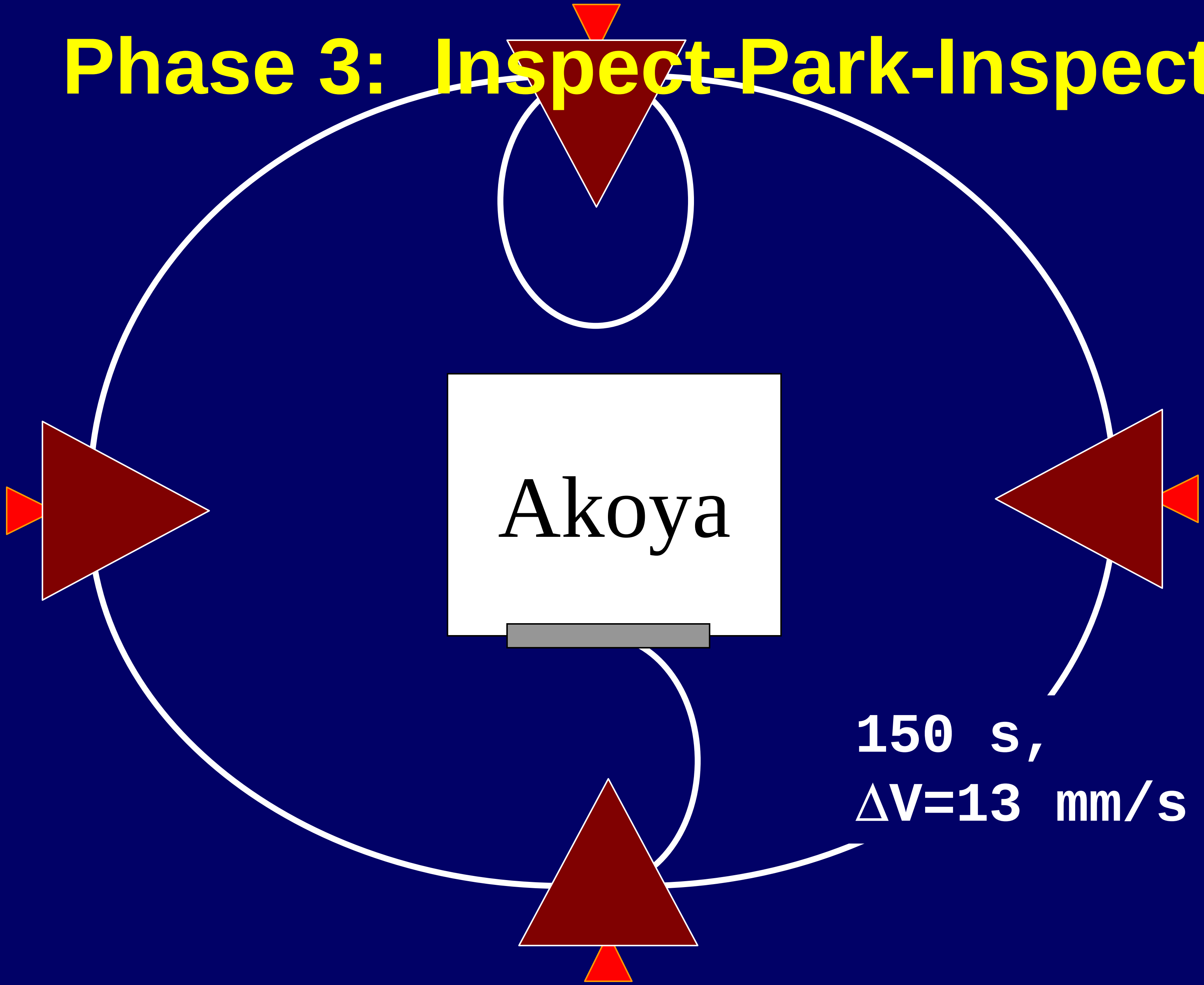



- Incremental demonstration of docking and maneuvers
- Phase 0: Release-Dock (10 mm/s, 20 seconds)
- Phase 1: Park (18 mm/s, 10-15 minutes)
- Phase 2: Inspect (71 mm/s, 20 minutes)

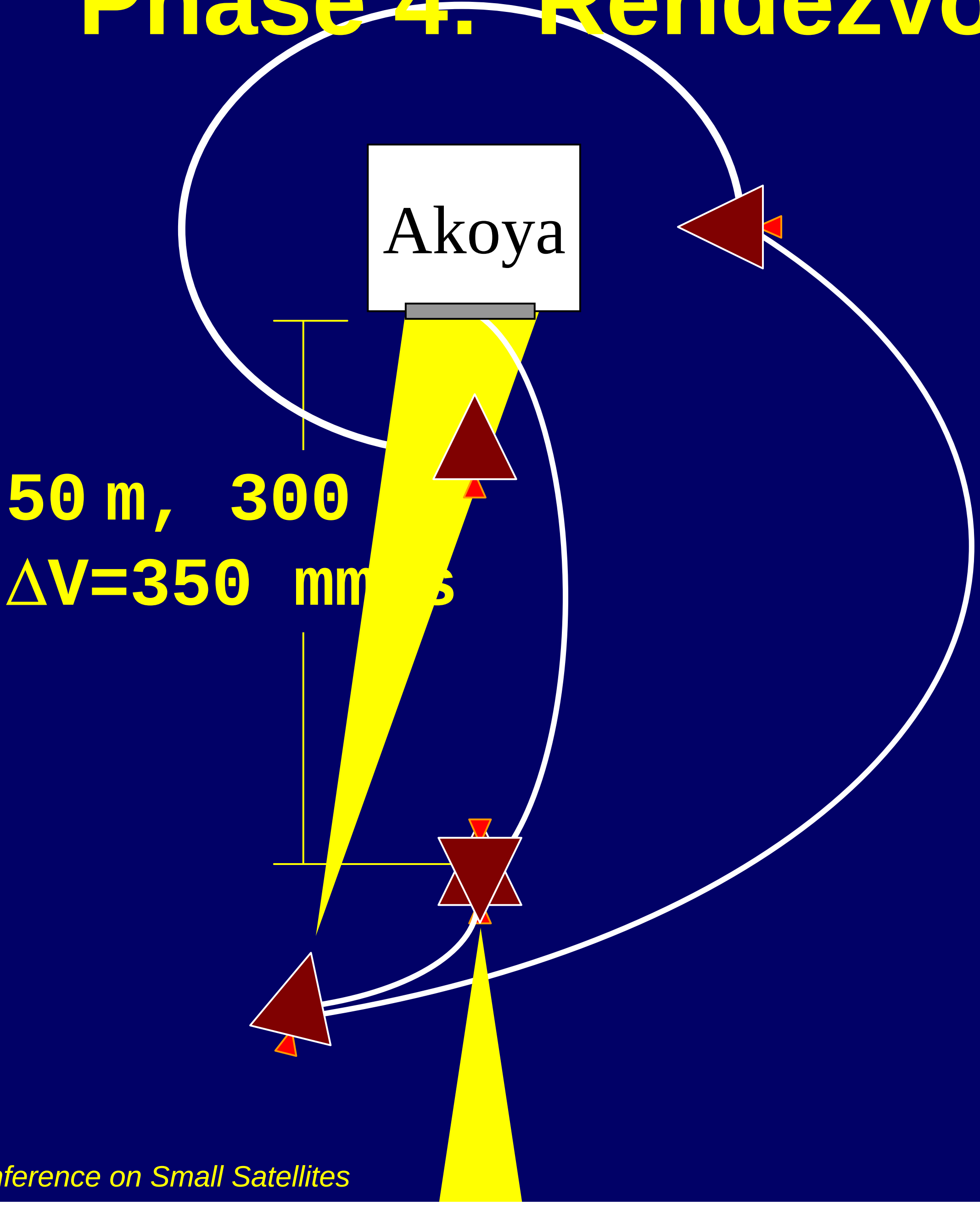
# Phase 2: Inspect



# Phase 3:  Inspect-Park-Inspect



# Phase 4: Rendezvous



# Maneuver Budget Recap

- Maneuvers
  - Phase 0:  Release-Dock (10 mm/s, 20 seconds)
  - Phase 1:  Park (18 mm/s, 10-15 minutes)
  - Phase 2:  Inspect (68 mm/s, 21 minutes)
  - Phase 3:  Inspect-Park-Inspect (115 mm/s, 20 min)
  - Phase 4:  Rendezvous (750 mm/s, 25 min)
- Baseline mission
  - 10 P0, 5 P1, 5 P2, 2 P3, 1 P4
  - ~1500 mm/s (x3 for uncertainty) = 4.5 m/s

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- Subsystem Details
  - Structures & Mechanisms
  - Propulsion
  - Imaging
  - Flight Controls
- Prototyping
- Conclusion and Future Work

# Structures & Mechanisms

- Carbon-fiber shells
- Aluminum docking arms
- Solenoid holds open (default/unpowered closed)

| Component | Mass (grams) |
|---|---|
| Propulsion | 510 |
| Batteries | 100 |
| Shell | 15 |
| Imaging system & transceiver | 125 |
| Internal frame | 100 |
| Control electronics | 50 |
| *Margin* | *100* |
| **Total** | **1000** |

# Propulsion


courtesy VACCO


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- VACCO ChEMS Micro-Propulsion System (MIPS)
- Identical the MIPS flown on MEPSI (Shuttle-launched, Dec. 2002)
- Specifications:
  - 510 grams
  - 55 mN Cold Gas Thrust
    - 0.25 mm/s impulses
    - 34 m/s total $\Delta V$
  - 3-axis turning
  - Forward/backward thrusts

# Imaging & Image Processing


- COTS wireless camera (300 m range)
- Image processing on Akoya
  - G4 (or equivalent) processor
  - Navigates relative to parent spacecraft
  - Markers on Akoya for position determination (TBD:  LEDs v. colors)
- Image processing algorithms an extension of those used by Lewis (“the robot photographer”)

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# Incremental Prototyping

- Hovercraft
  - Propeller-based propulsion
  - Autonomous navigation (light-seeking)
  - Demonstrate electronics, communications, control in 2-D operations
- Balloon
  - Ducted fans in flight configuration
  - Demonstrate quasi-3-dimensional operations

# Future Work

- Microgravity experiment (NASA KC-135)
  - Docking/maneuvering tests using flight-equivalent hardware
  - Fans or thruster depending on flight safety approval
- Detailed flight simulator
- Enhancements
  - Recharging
  - Telemetering (temperature, voltage, comm)

# Bandit is high-risk, high-payoff

- Incremental operations to manage risk
  – Operational constraints
  – Flight-safety constraints
- Demonstrations
  – Autonomous image-based navigation
  – Repeatable docking
  – Extremely small envelope
- We should do this again!
  – Universities can take risks that “professionals” shouldn’t
  – Fantastic training environment

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