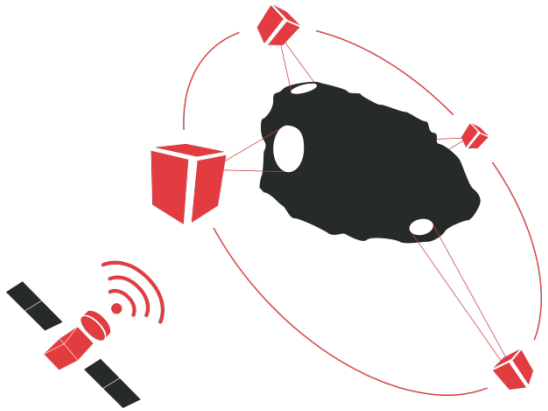
a.i. solutions

a.i. solutions SmallSat Formation Flying Testbed

CubeSat Workshop 2014



Smarter approaches. Better results.

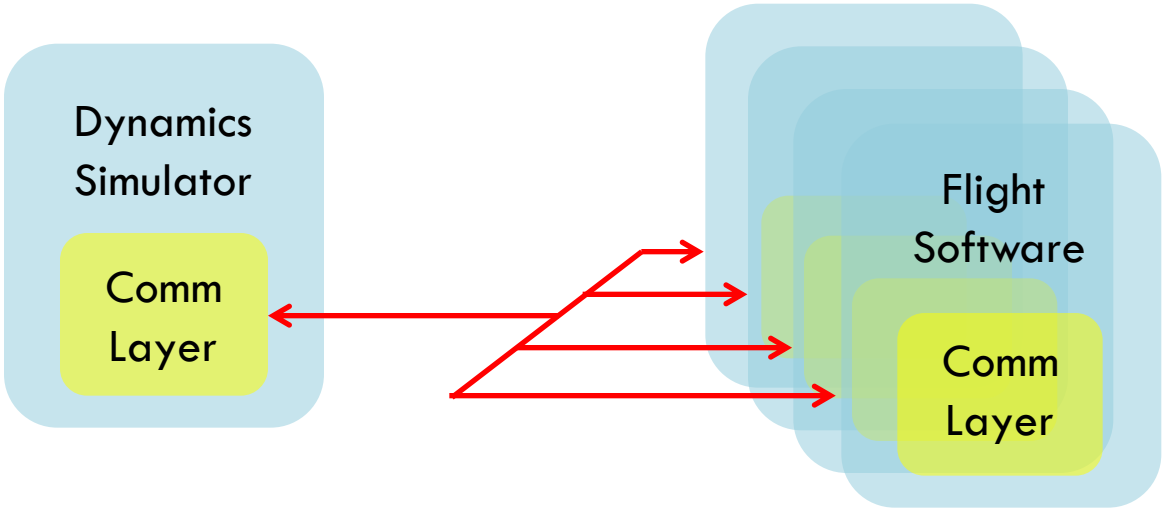
The Big Picture – Goals

- **Ultimate Goal:**
  - Create Onboard Autonomous Formation Flight Capability for Small Spacecraft

- Goals Along The Way:
  - Encapsulate existing knowledge and gain new knowledge in:
    - Formation Control
    - Attitude Control
    - Flight Software

The Big Picture – How We Are Getting There

- Developing a Closed-Loop Formation Flying Testbed to:
  - Simulate spacecraft dynamics for N-spacecraft
  - Simulate RTOS Flight Software (FSW) for N-spacecraft with realistic memory and processor constraints
  - Simulate inter-spacecraft communications



Potential Applications of …

- Closed-Loop Formation Flying Testbed:
  - Formation Design & Analysis
  - FSW Design & Testing

- Onboard Autonomous Formation Flight Capability for Small Spacecraft:
  - Inexpensive stereo imaging of objects of interest
    - Asteroids
    - Space Debris
    - Earth
  - Distributed spatial measurement experiments
    - Sparse-aperture telescopes
    - Gravity mapping
    - Magnetic field mapping
    - Lower Thermosphere/ Upper Mesosphere atmospheric research
  - Advanced maneuvering
    - Autonomous collision avoidance
    - Autonomous docking

Dynamics Simulator (DSim)

Flight Software (FSW)

Shared Object Server (SOS)

R&D Activities 2014

DYNAMICS SIMULATOR (DSIM)

DSim Features

Purpose: DSim is a software application that enables simulation of rigid body dynamics with a task-based interface.

- Coded in Python

- Extensibility and Optimization with Cython

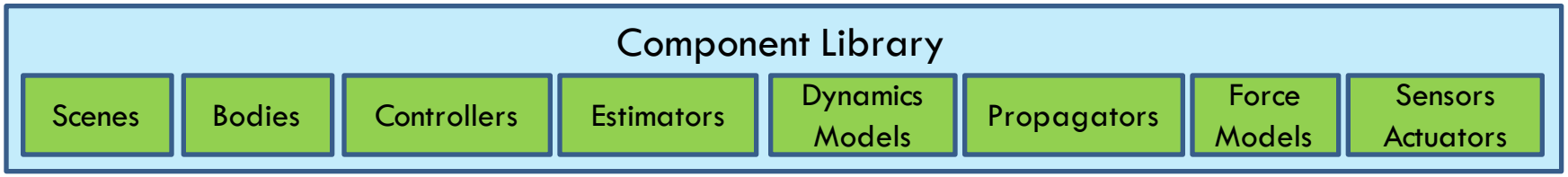
- Symbolic equations of motion (EoM)'s using SymPy

- Dynamic EoM's with Kane's method

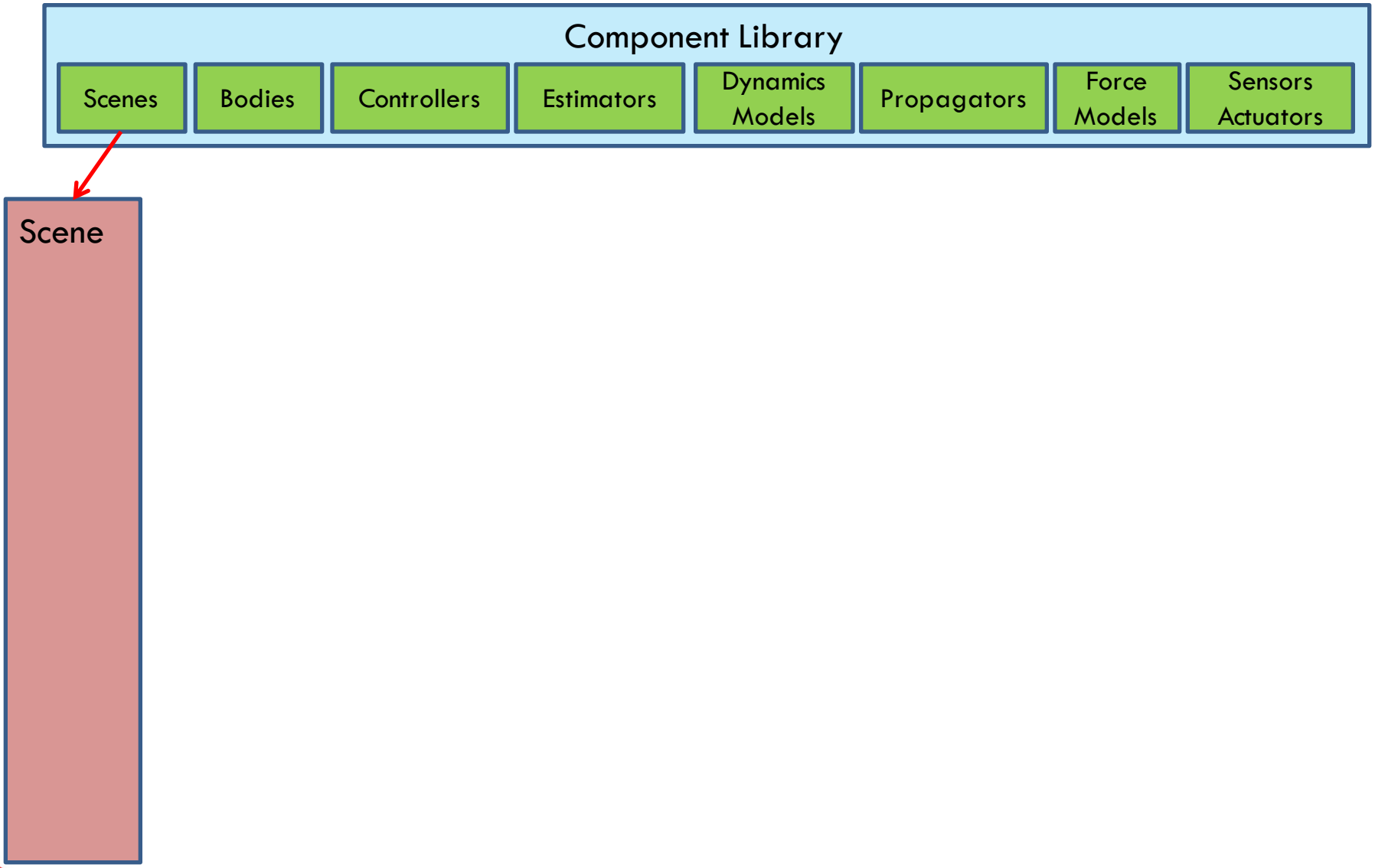
- Task execution framework

```
sc.task_manager.addTask(task_applySLMPIDControl,
                        'applySLMPIDControl')
```

DSim Use Case – Simulate a Formation



DSim Use Case – Simulate a Formation



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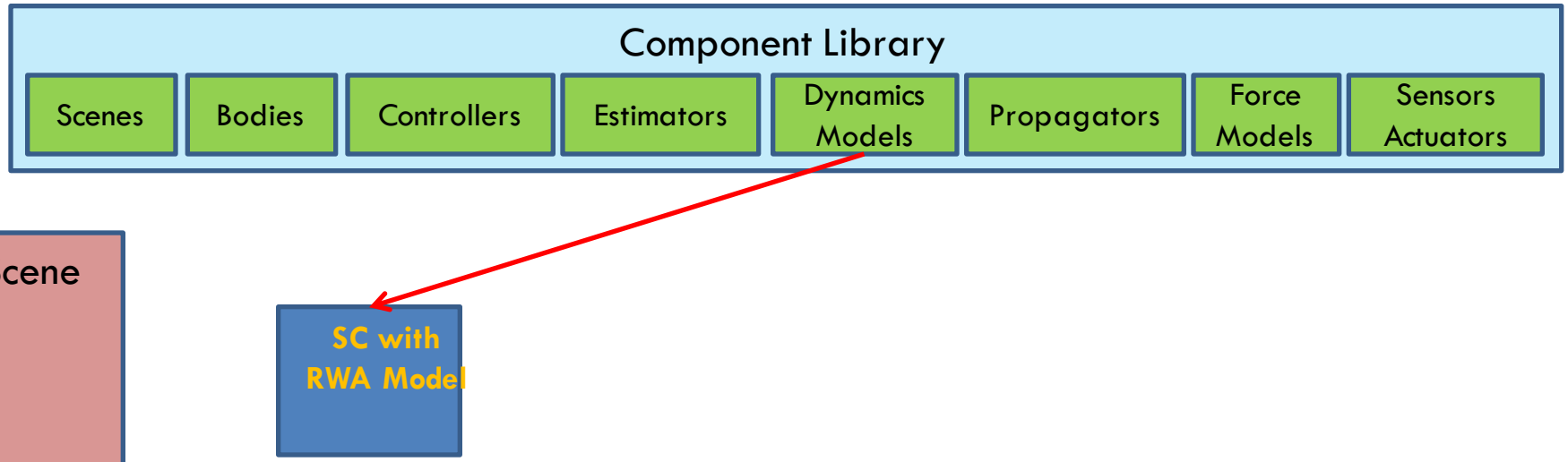

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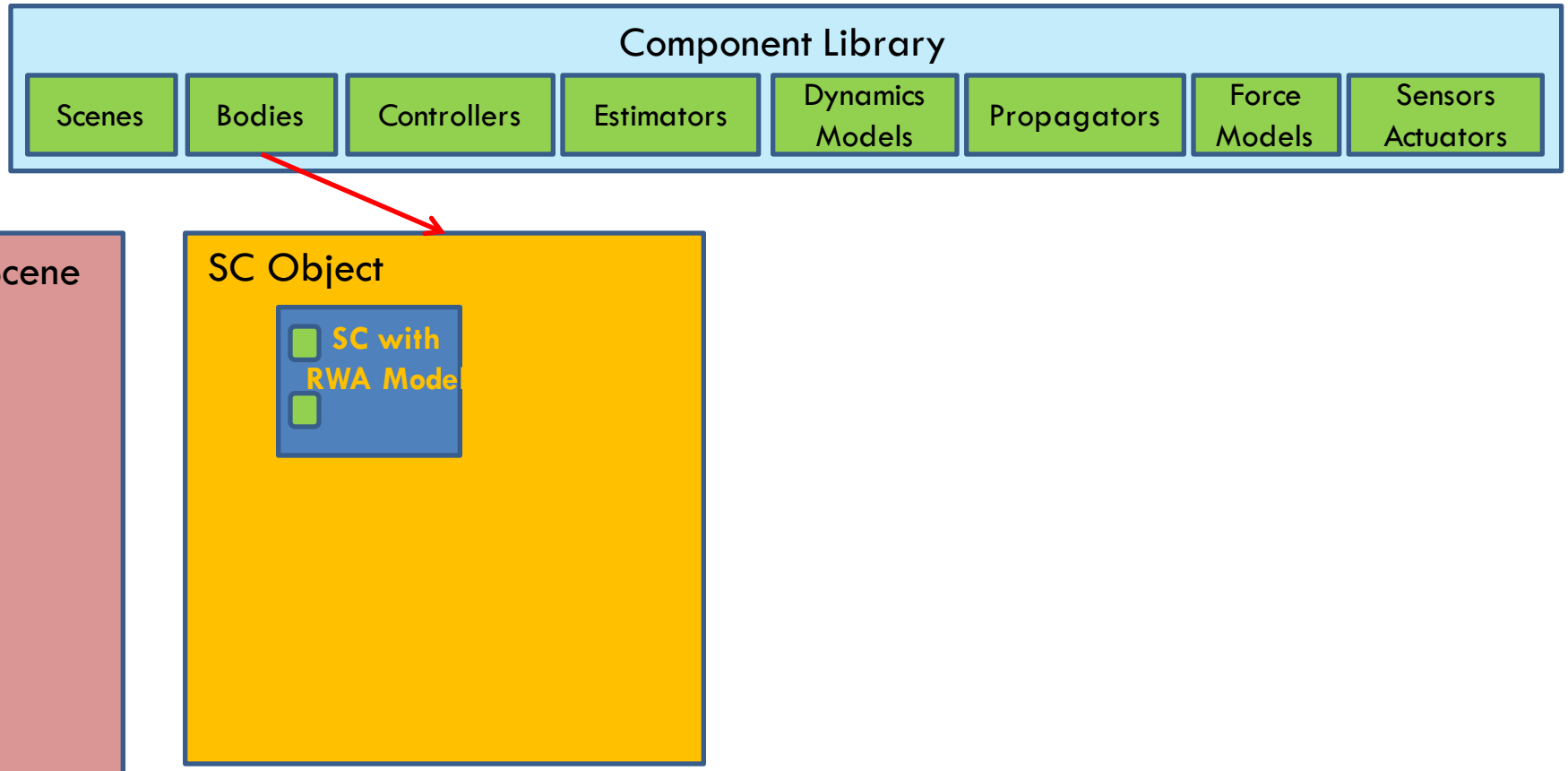

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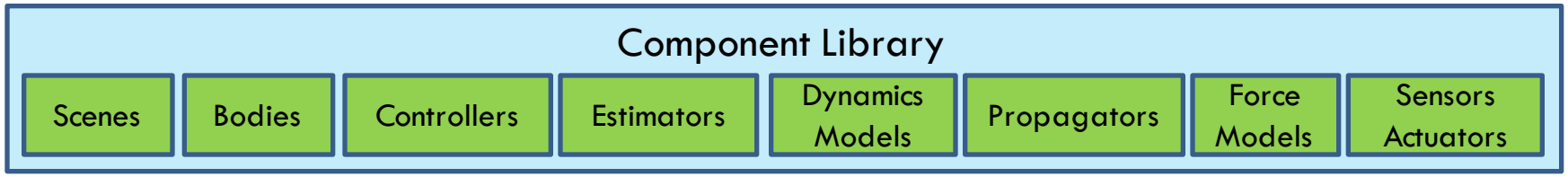

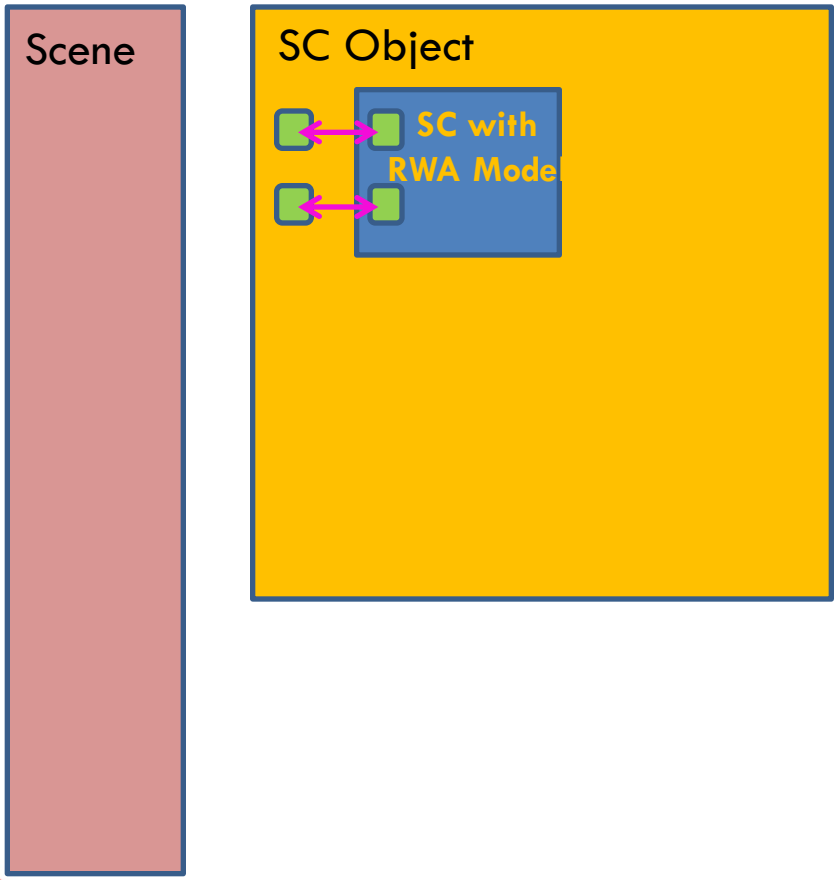

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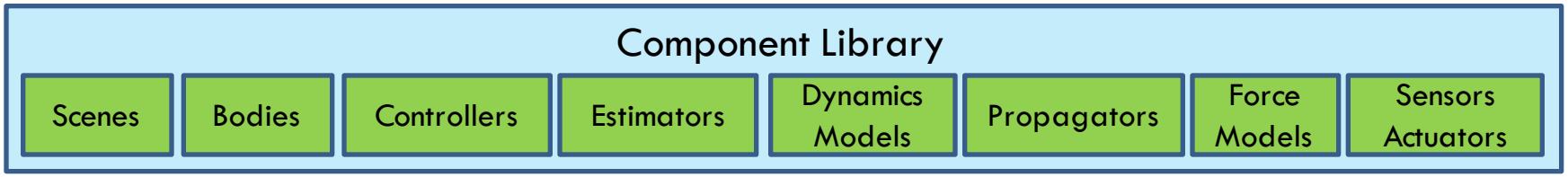

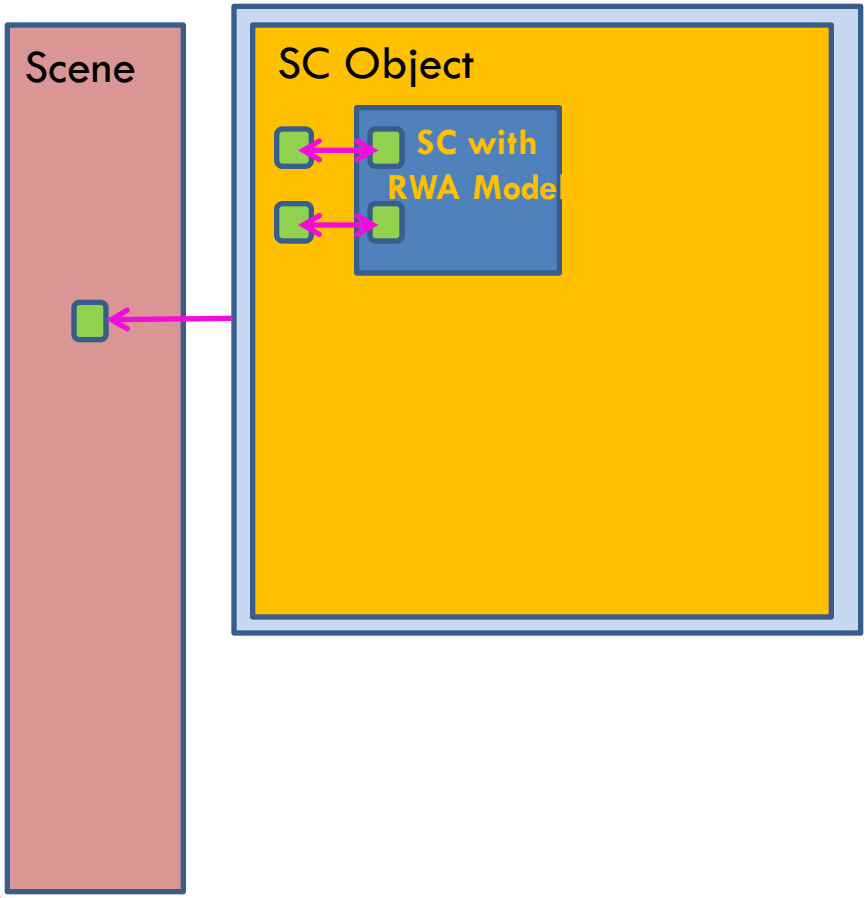

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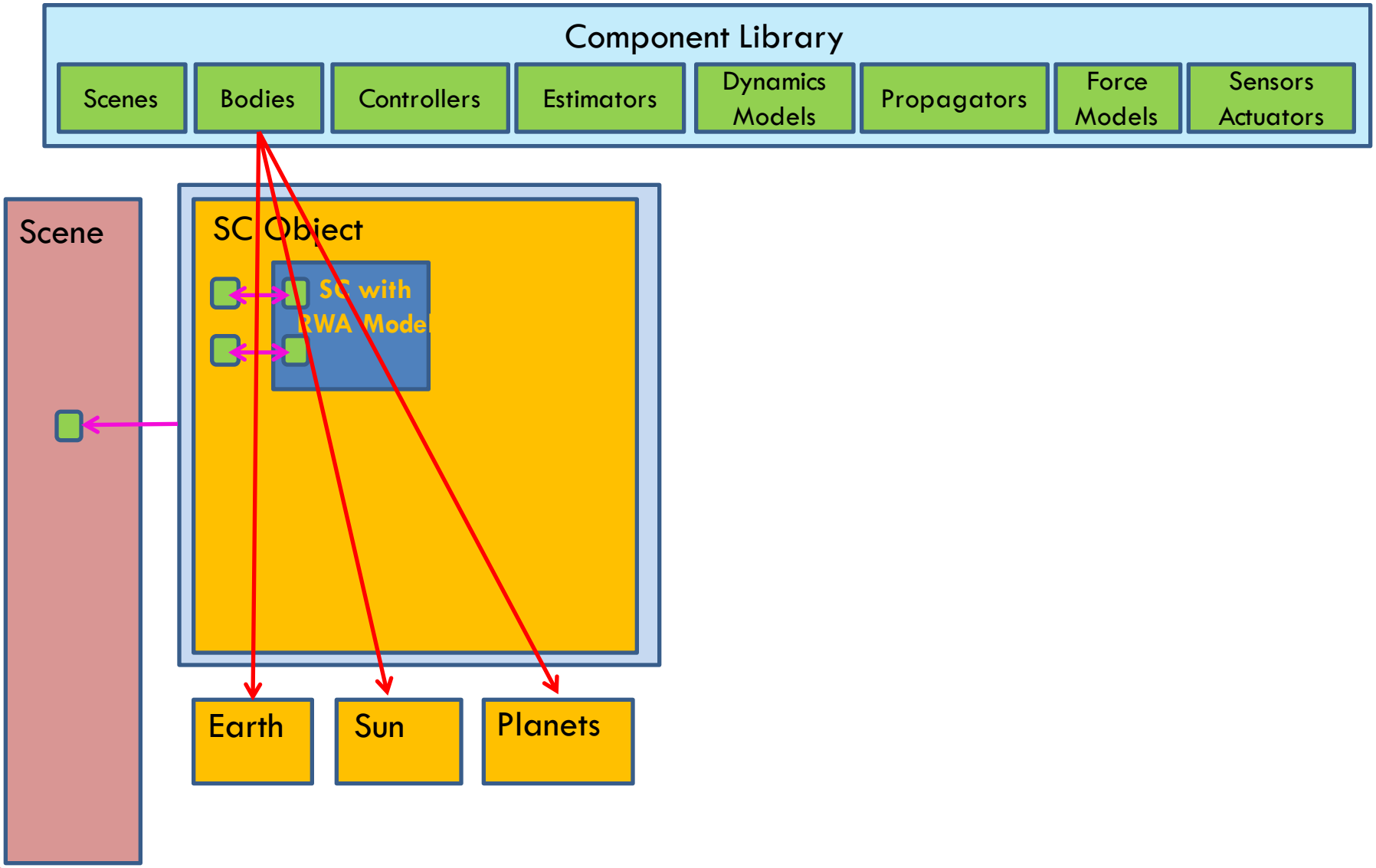

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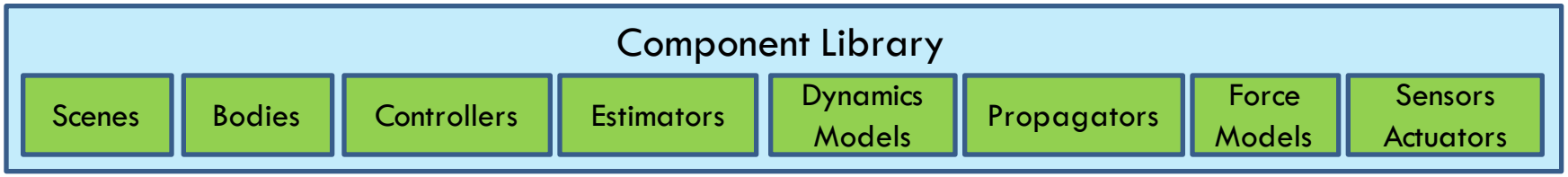

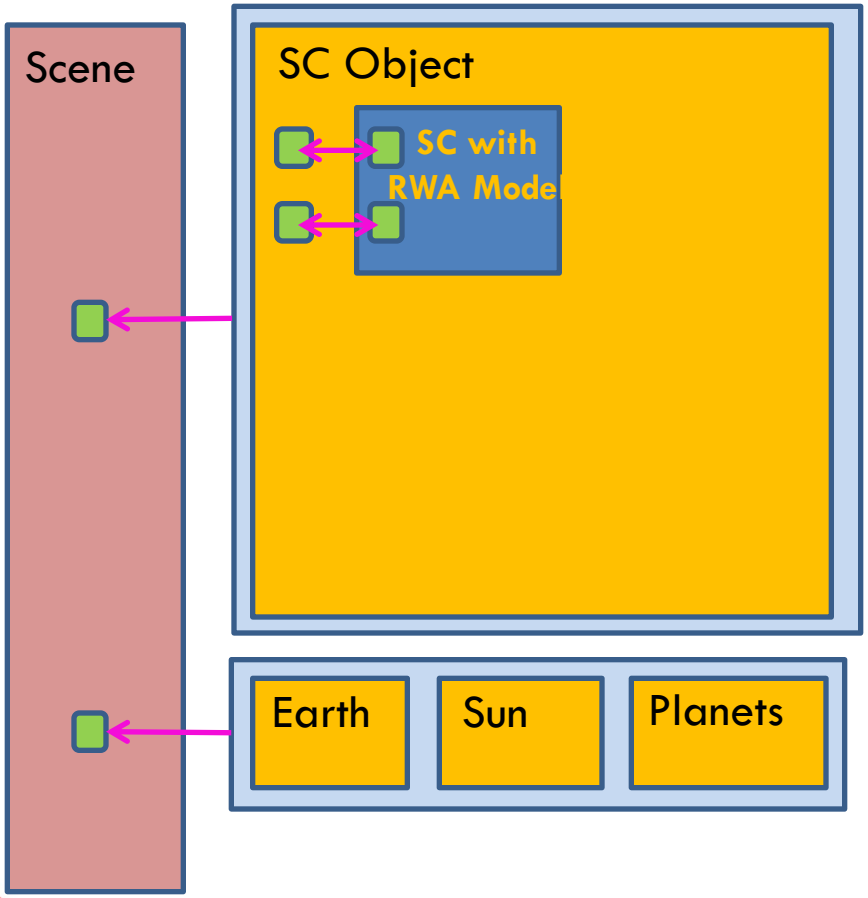

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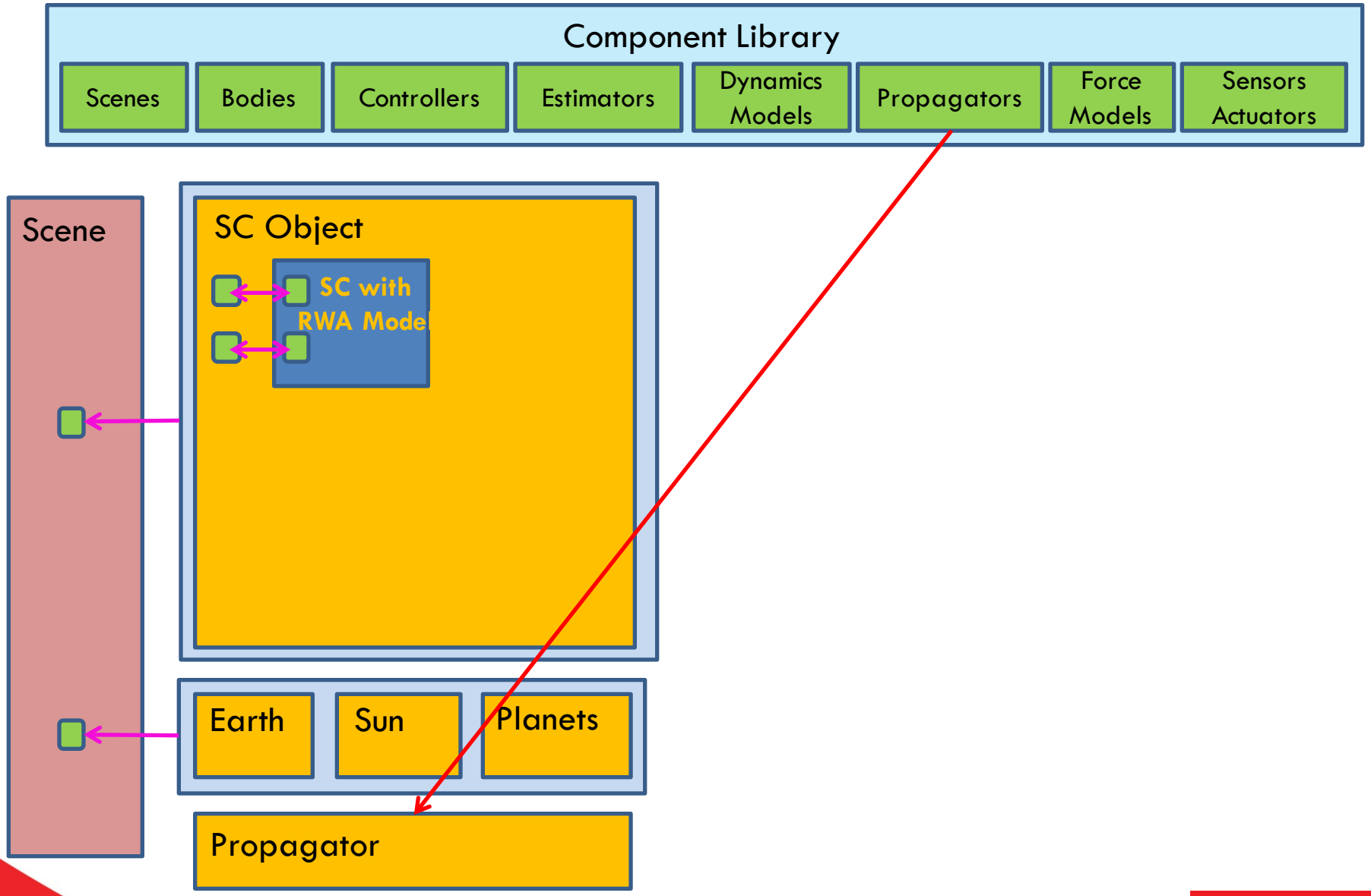

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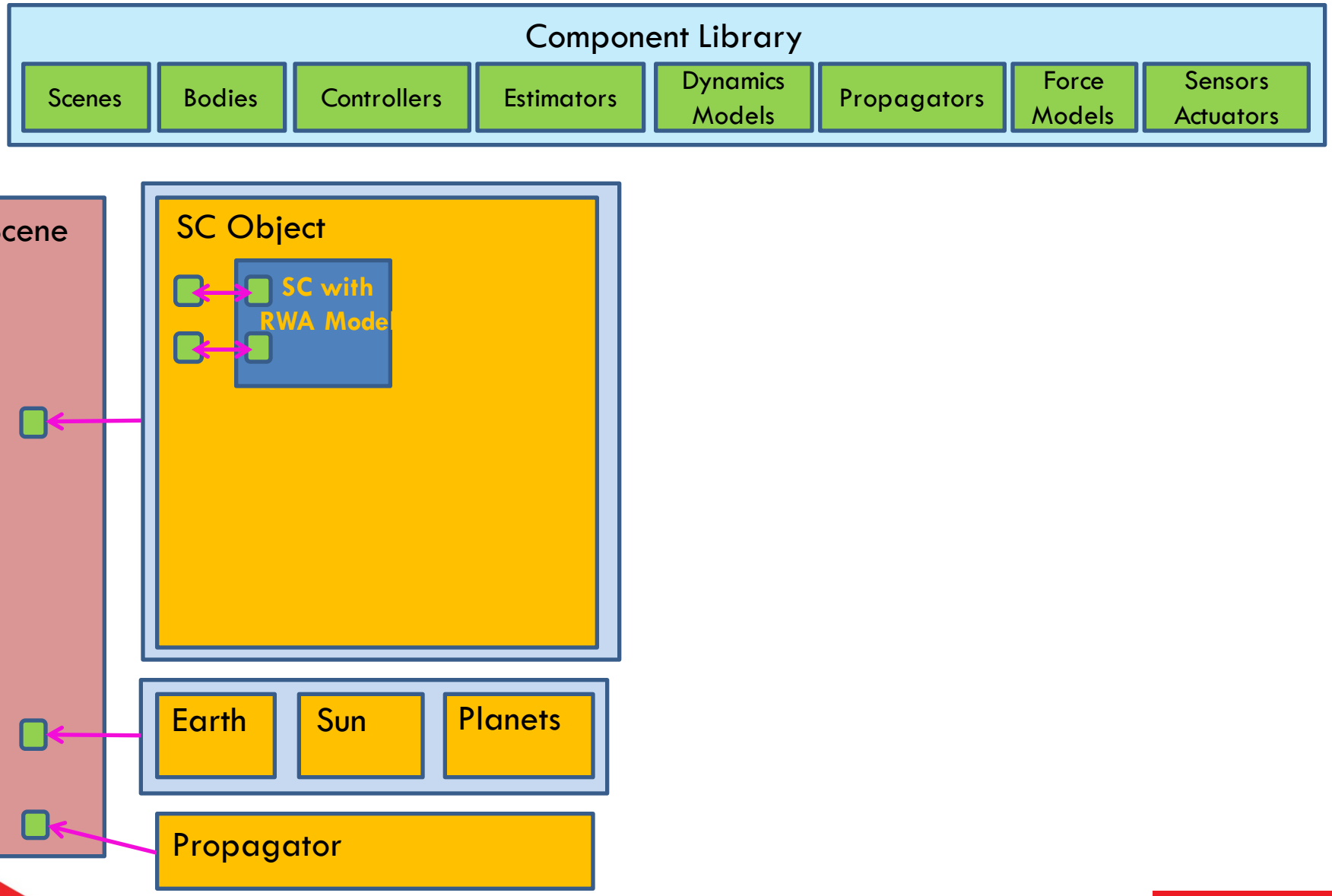

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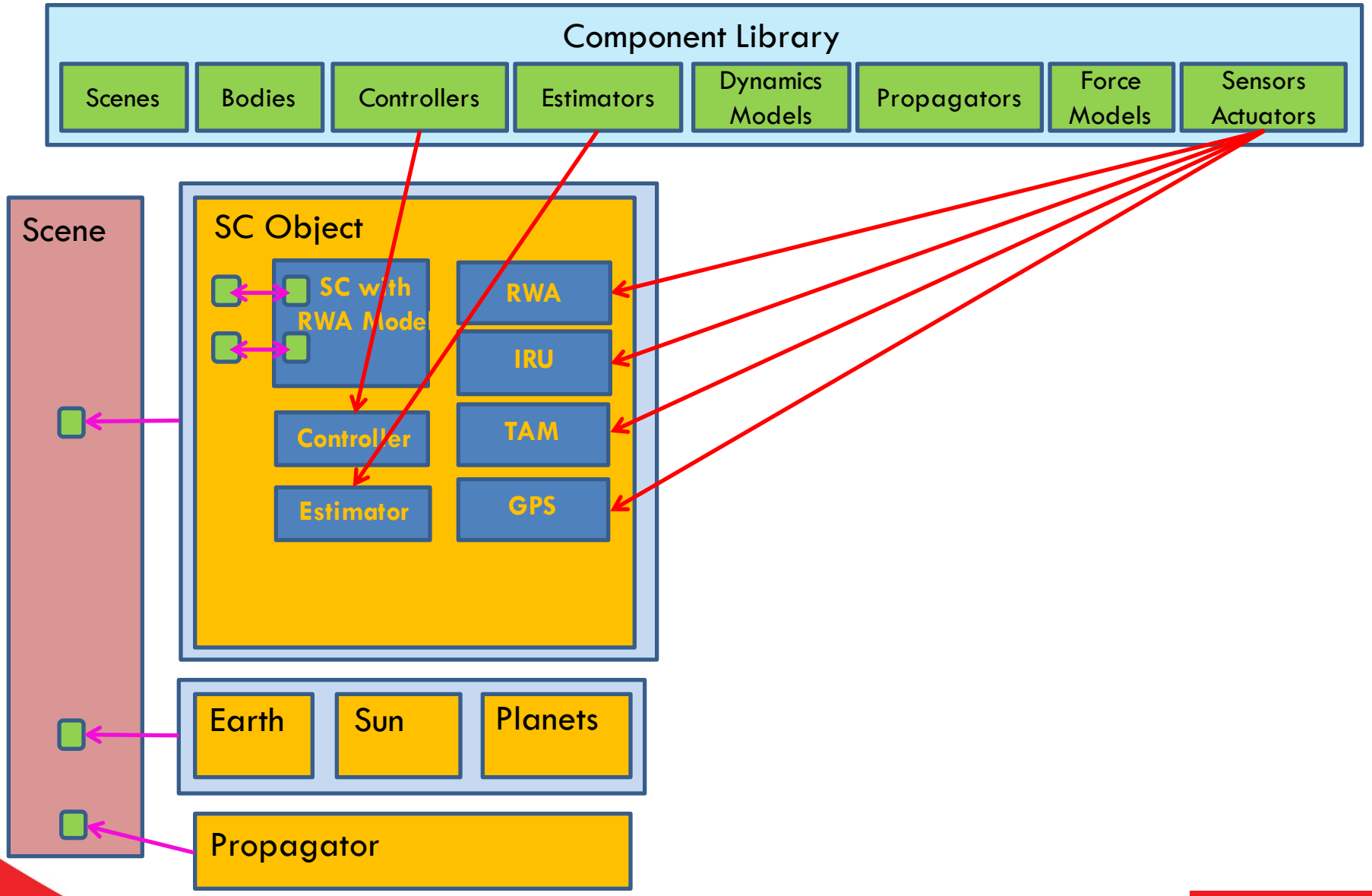

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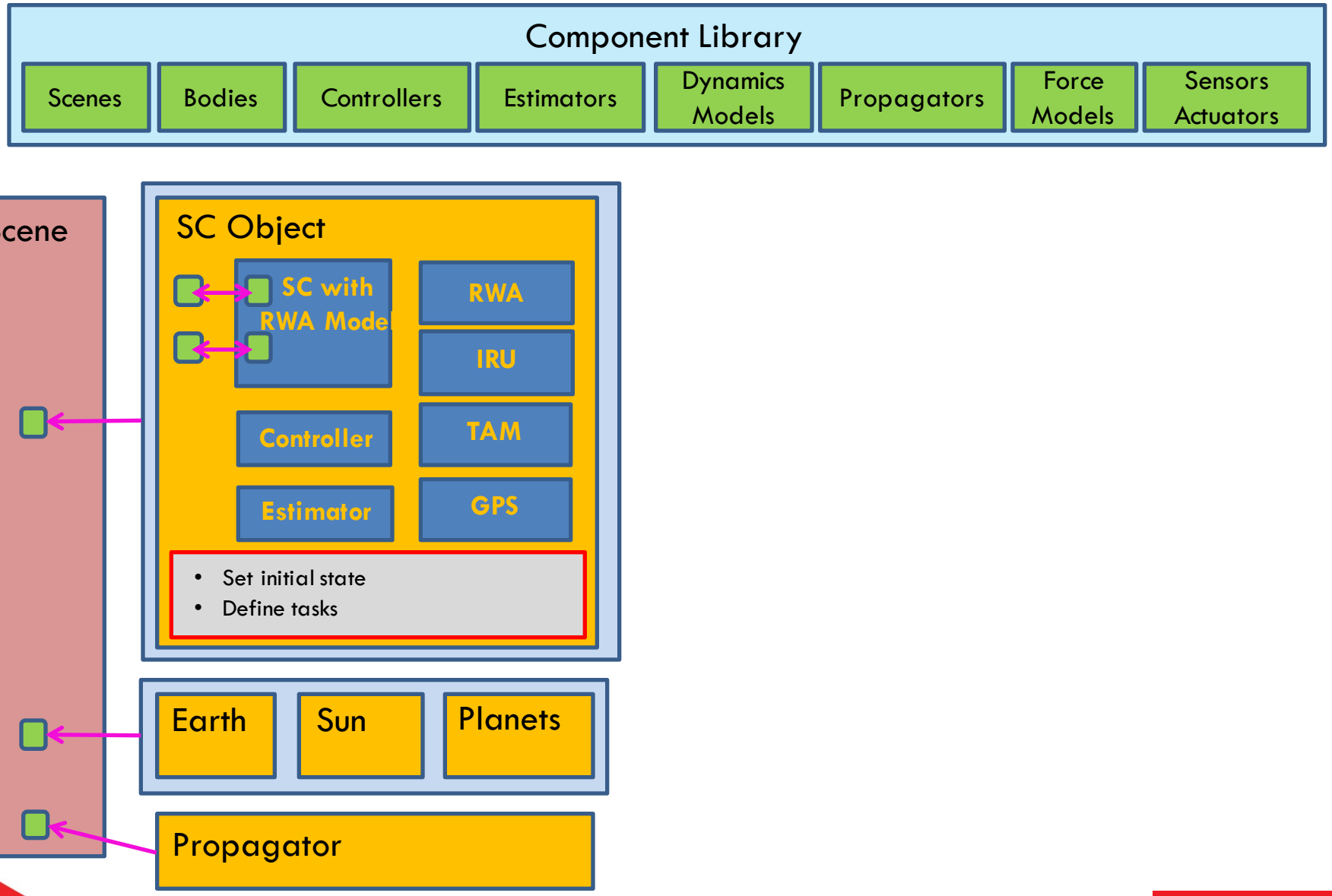
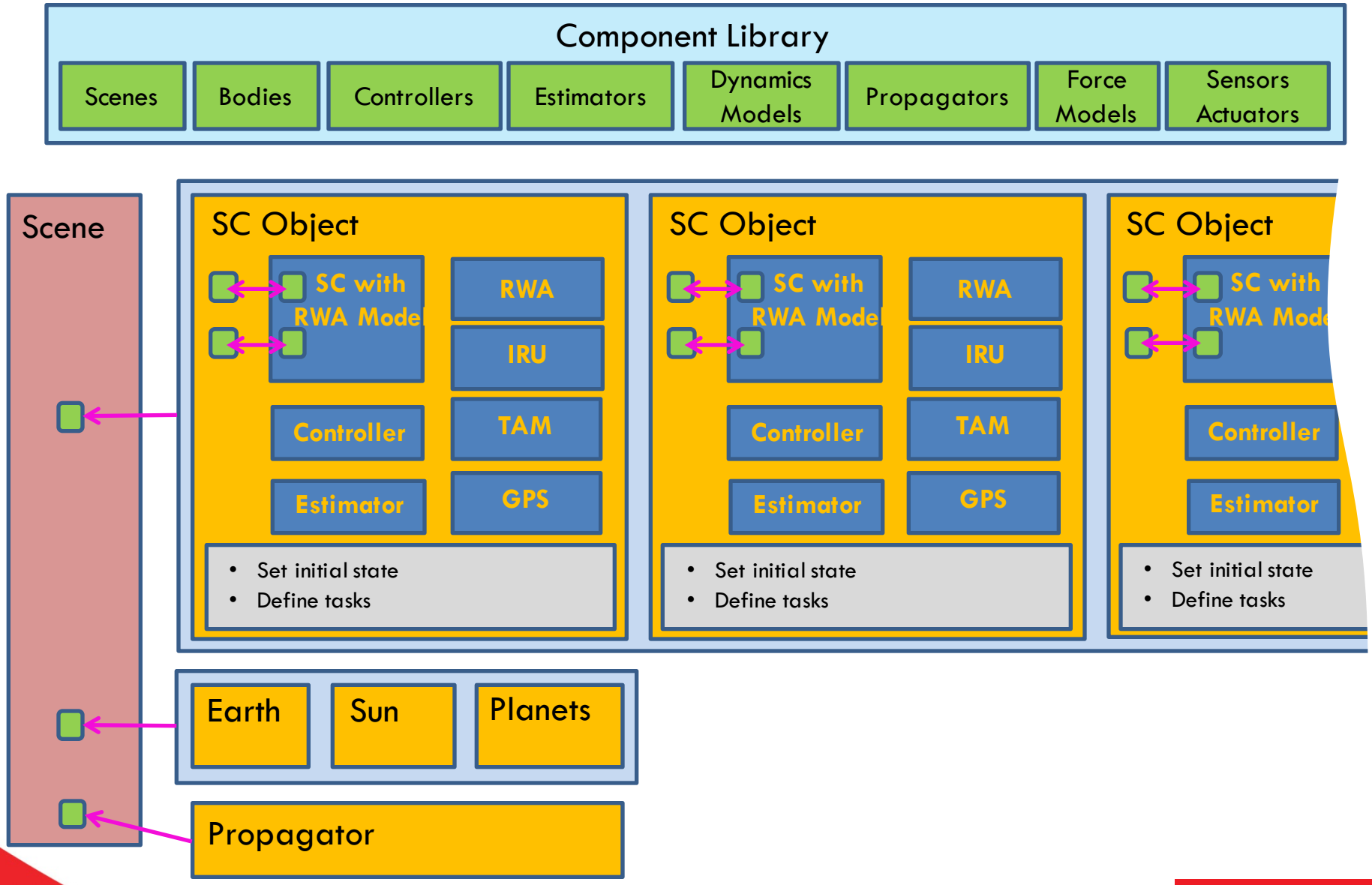


DSim Use Case – Simulate a Formation



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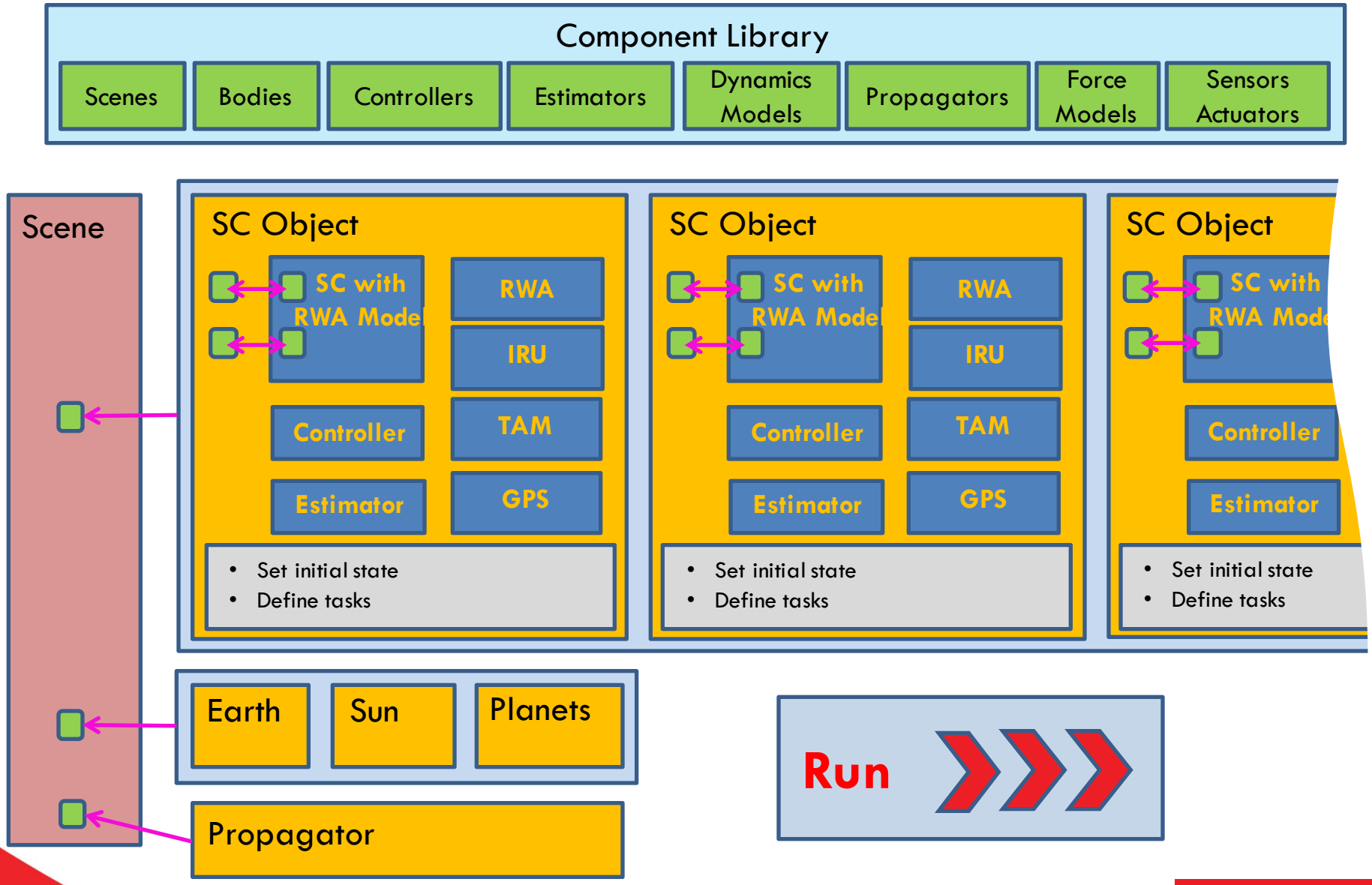
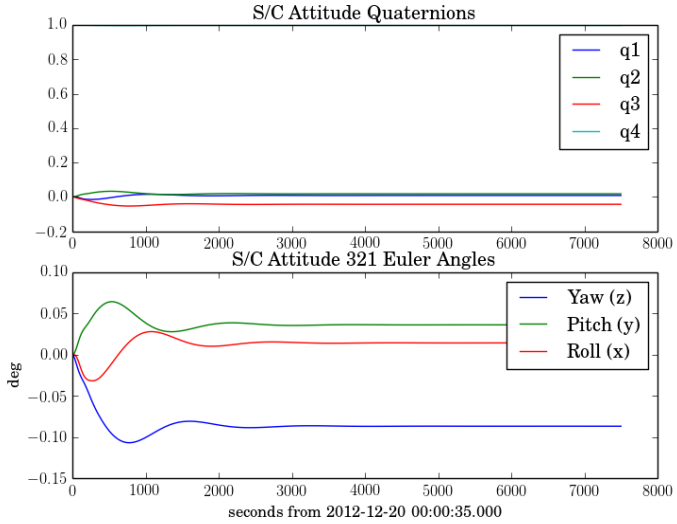
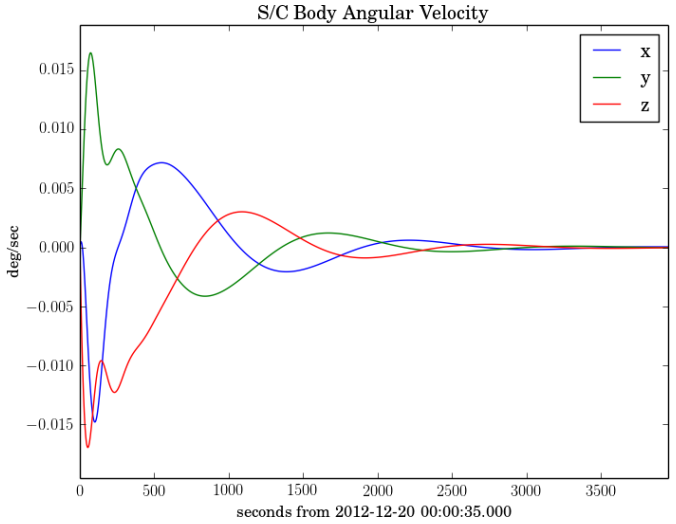
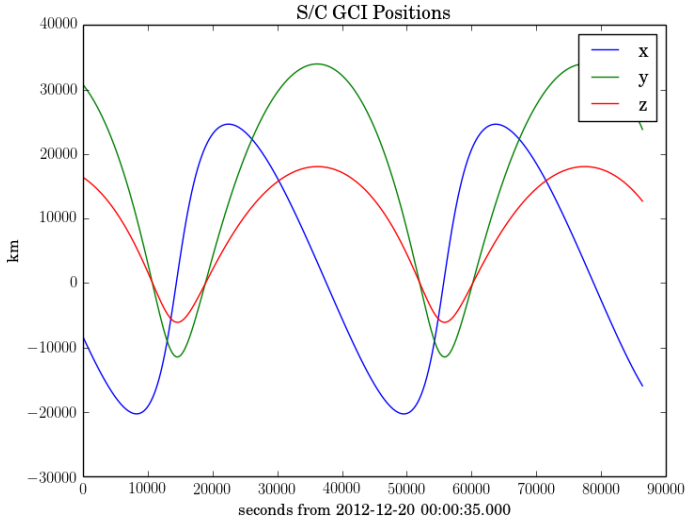
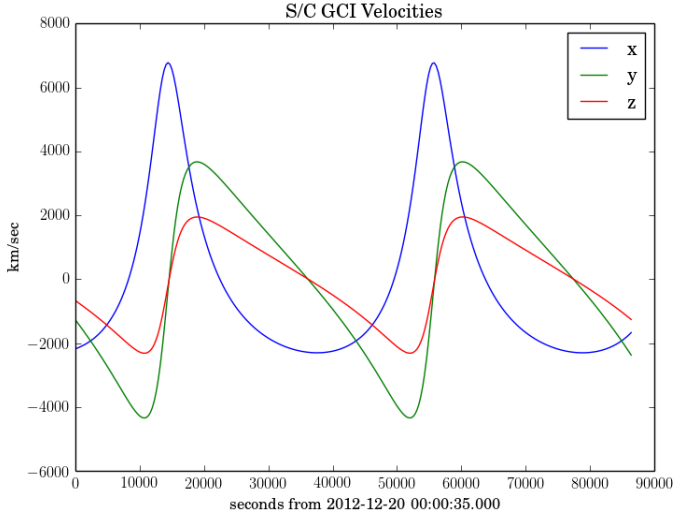


DSim Use Case – Spacecraft Kinematics

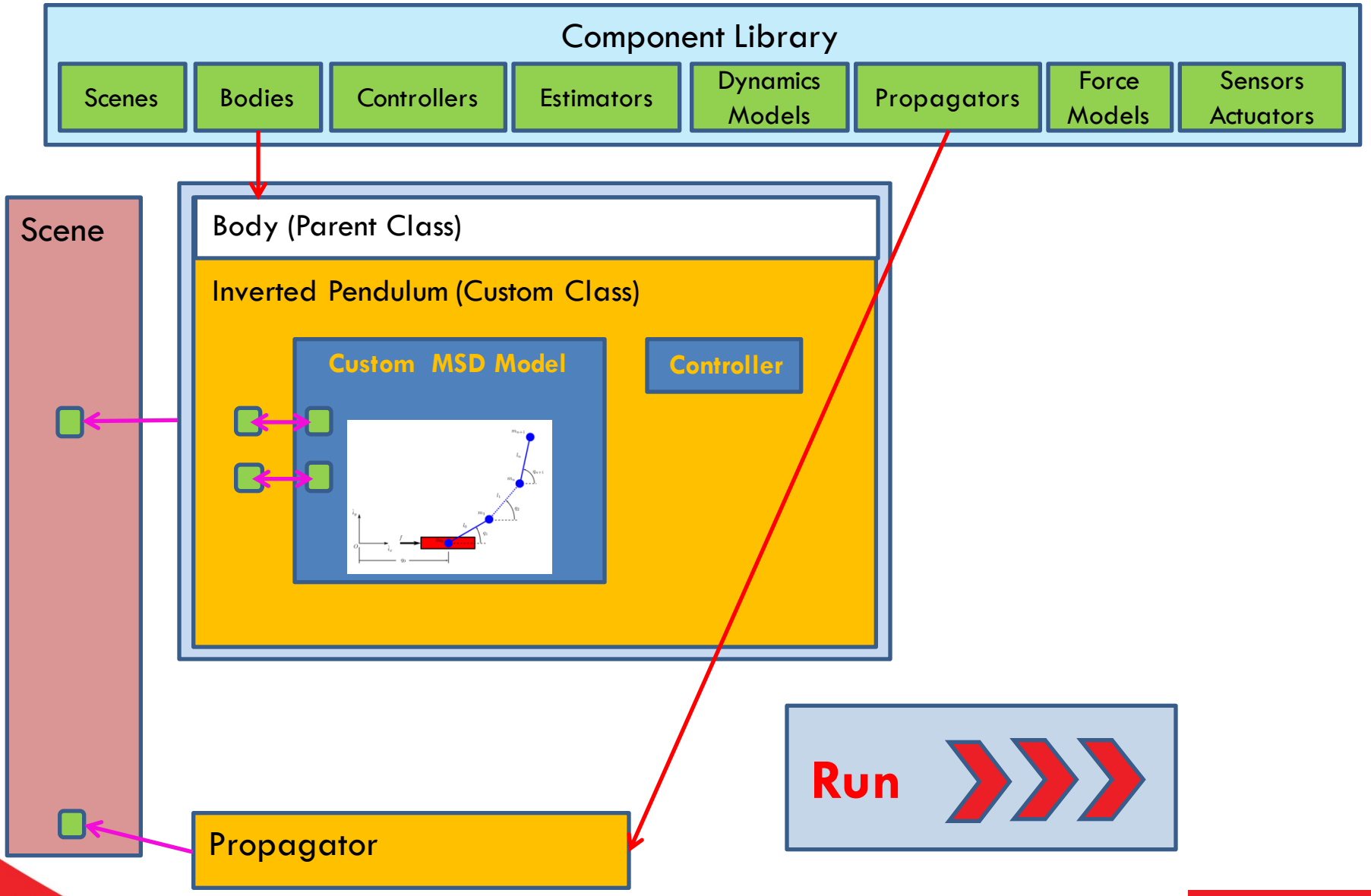








DSim Use Case – Simulate Inverted Pendulum



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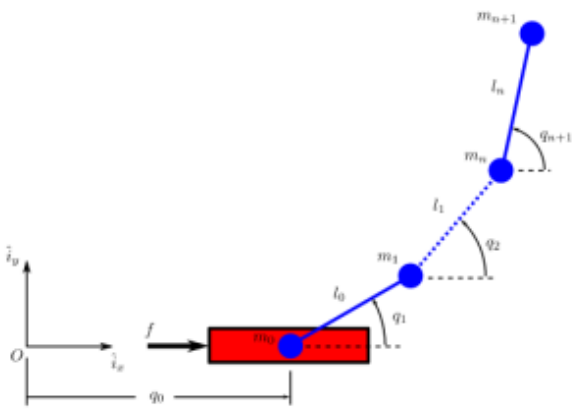
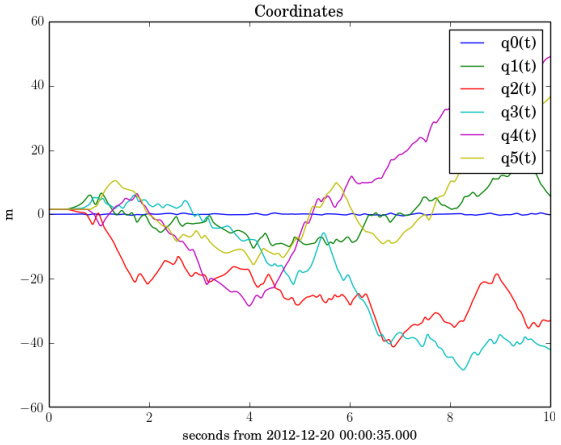
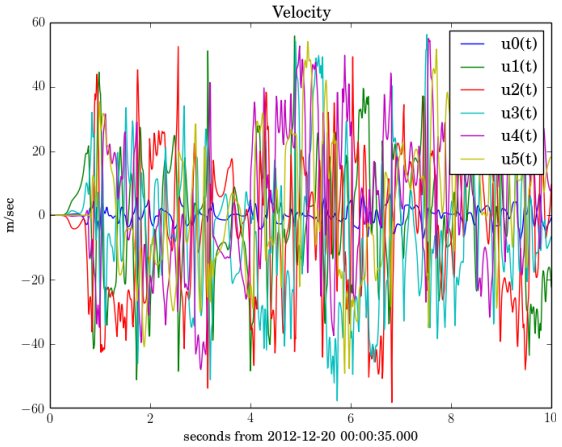
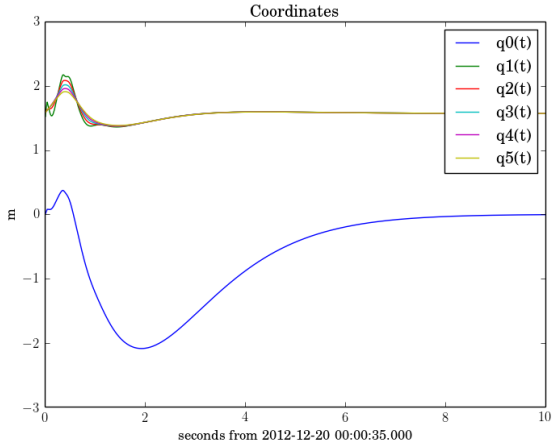


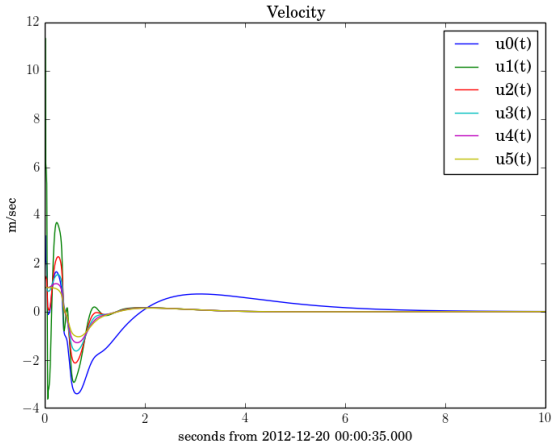
Uncontrolled Case





Controlled Case



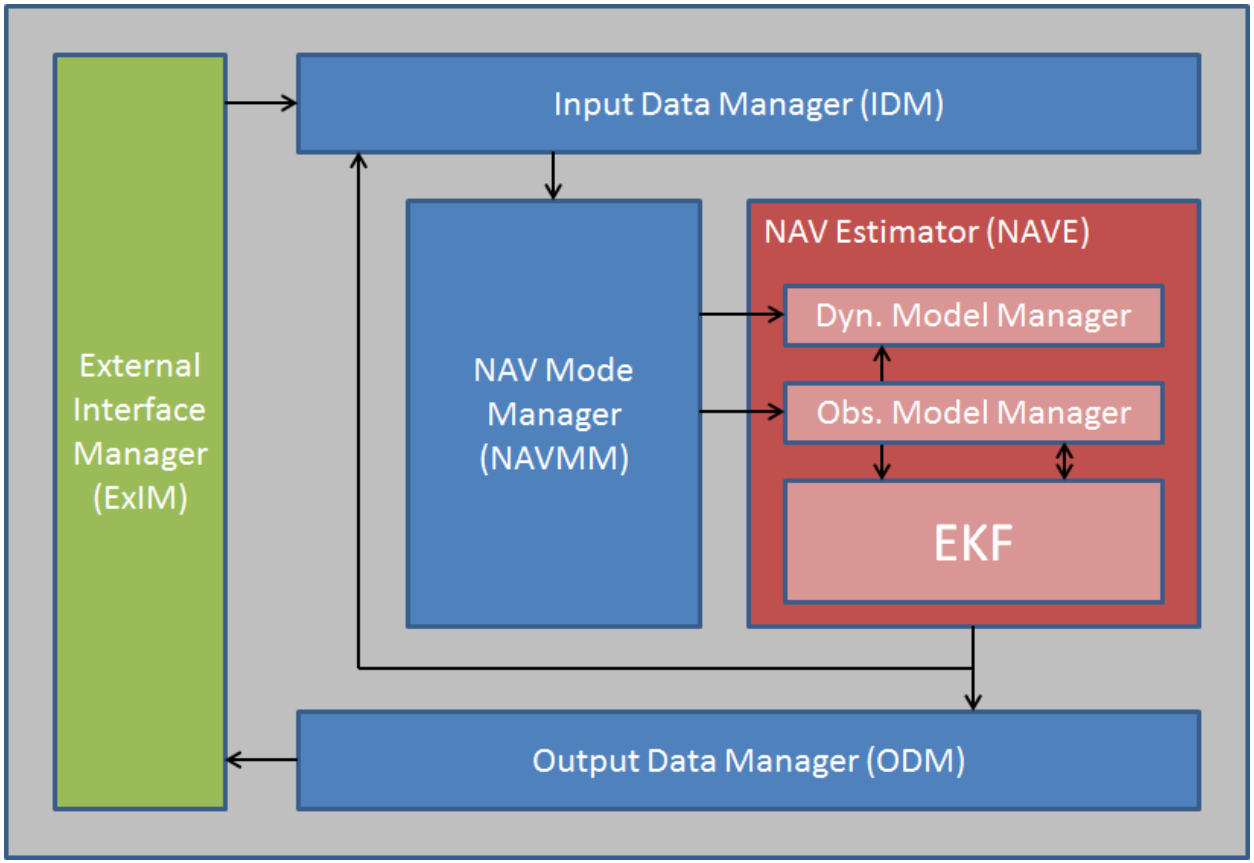


NAV FLIGHT SOFTWARE (FSW)

NAV FSW – High Level Architecture

Purpose: The NAV FSW is the navigation system prototype that is the first component of the GN&C flight software system.

- Overall design complete
- High level prototype working with estimation of simple harmonic oscillator
- Implemented in Python and running in Linux for prototyping purposes

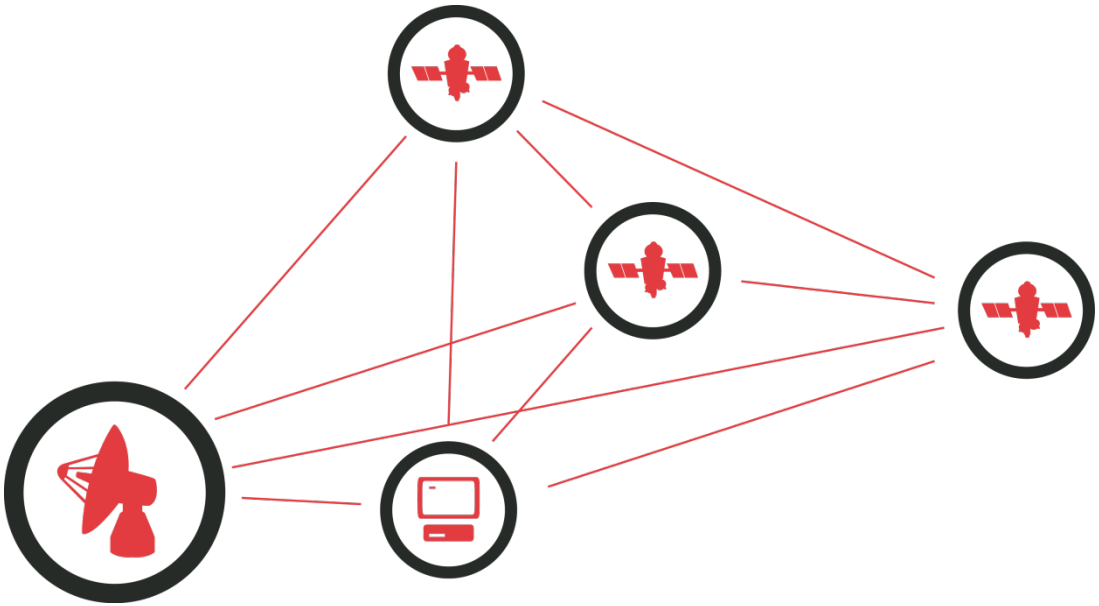


SHARED OBJECT SERVER (SOS)

SOS – High Level Description

Purpose: The SOS is a networking architecture designed to enable communication between FSW instances.

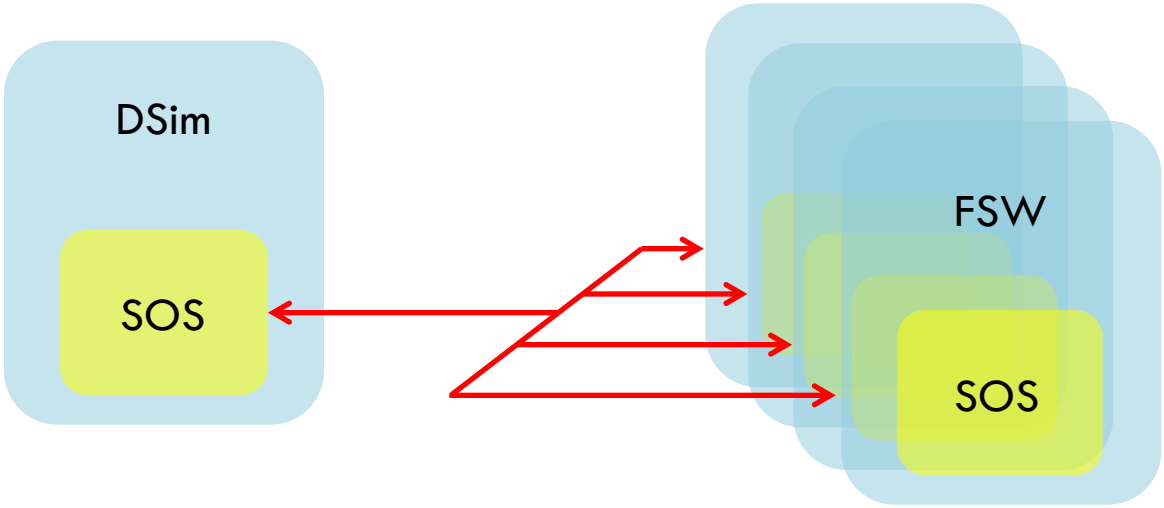
- Powered by node.js
- Uses ZeroRPC for remote Python–to-Python communication
- Provides network visualization feature to graphically represent the formation



DSIM + FSW + SOS = FORMATION FLYING TESTBED

Formation Flying Testbed Vision

- **Goals:**
  - Simulate a formation of spacecraft by spawning N virtualized FSWs
  - Model the formation dynamics with DSim
  - Enable communication between nodes with SOS



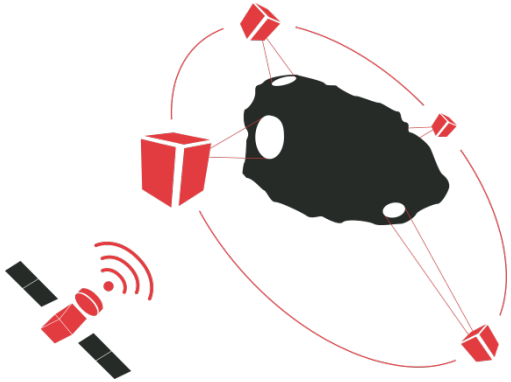
Autonomous Operations

Swarm Dynamics

FSW Testing

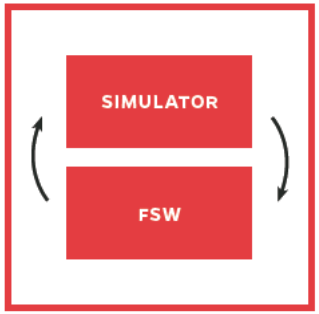
Planned
R&D Activities 2015

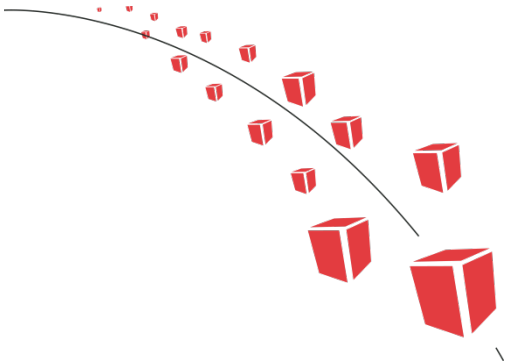
Planned R&D Activities 2015



- Implement autonomous operations algorithms

- FSW in the Loop Testing





- Investigate Swarm Dynamics