Entry And Guided Landing Environment (EAGLE)



Presenting EAGLE for SESP 2008

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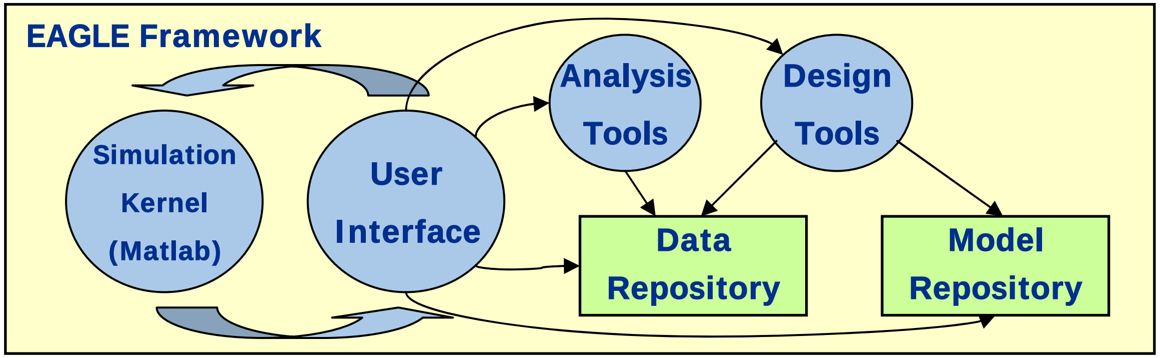
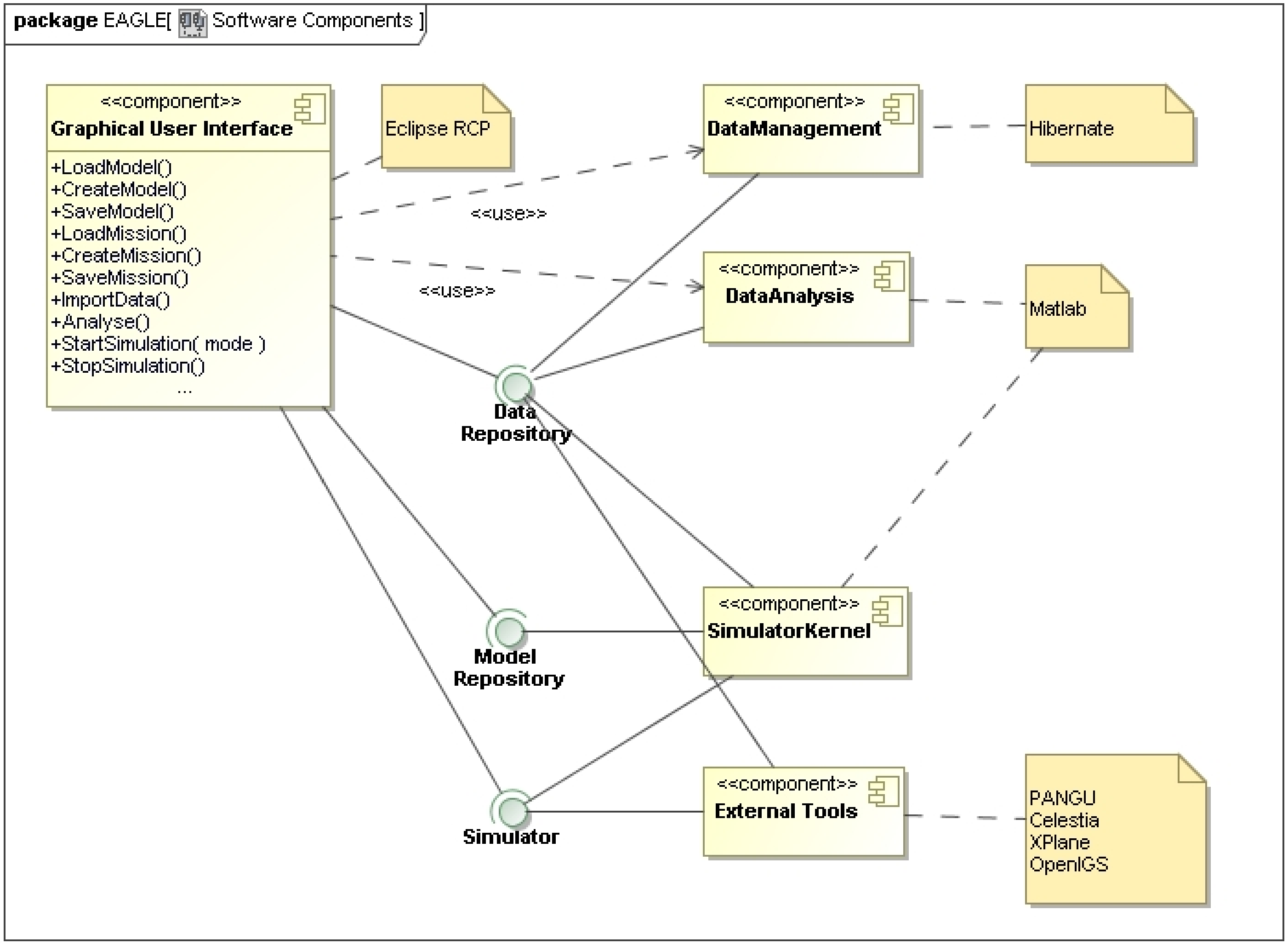
Overview

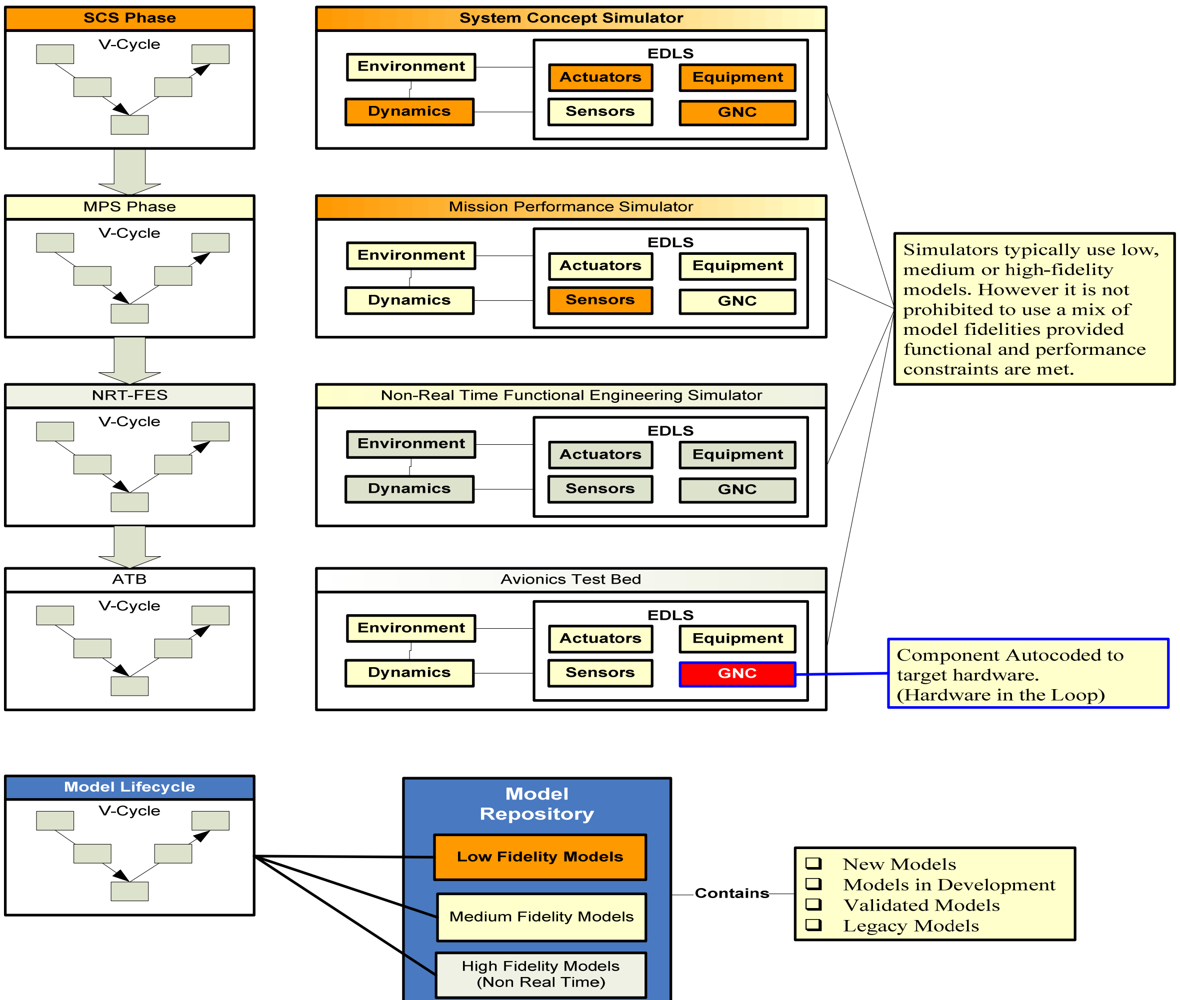
- Framework to design & develop EDLS.
  - ⇨ Focus on guidance, navigation and control algorithms
- Component based architecture design.
- Matlab as a core simulation kernel.
- Separate cross platform Graphical User Interface.
- Database connections to persist data.
- Model repository for CM, models and system configuration.
- Analysis and Design tools specific to user domain.



Software Components



Multiple Fidelity Levels



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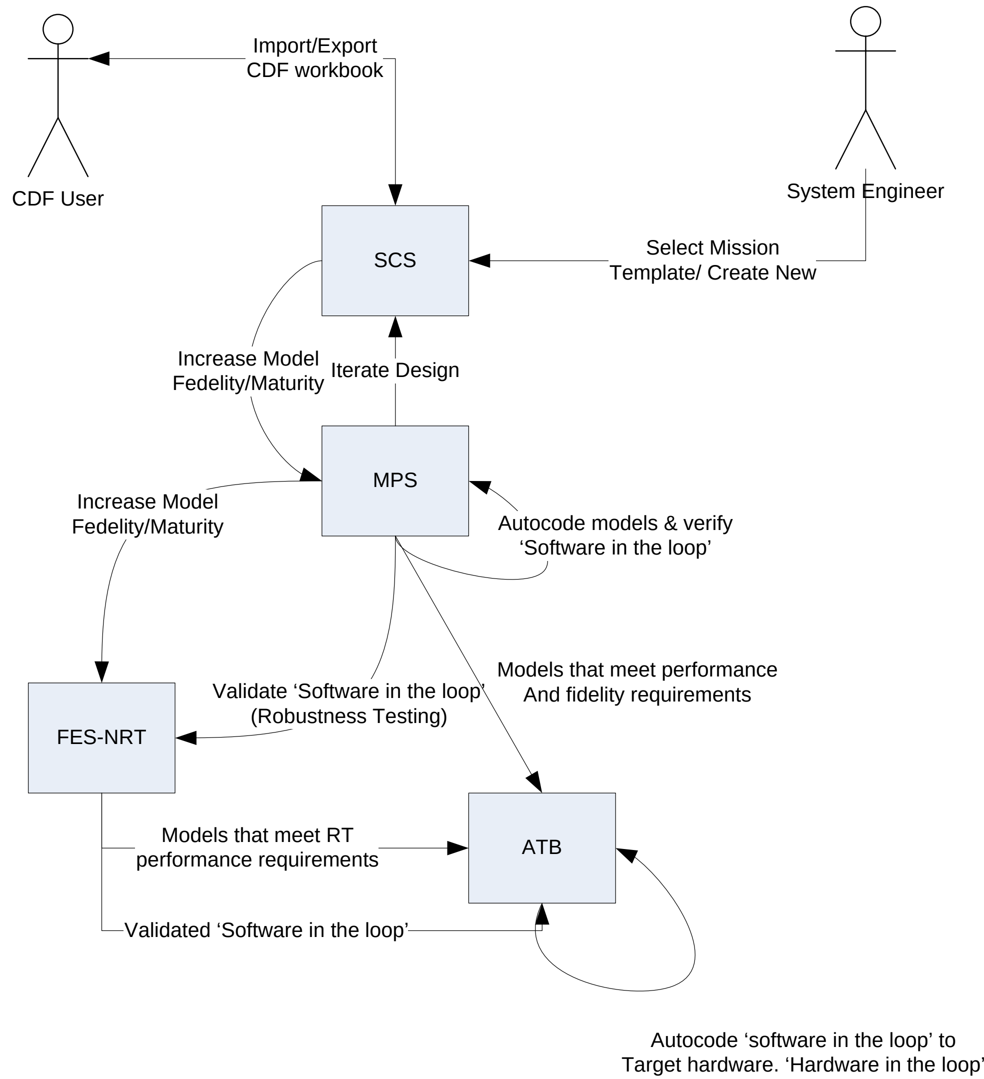
Simulation Workflow



System Concept Simulator

- In a desktop environment
  - ⇨ establish a low fidelity model of a spacecraft and its environment
  - ⇨ use this model to establish the feasibility of an EDL mission from the final Trajectory Correction Manoeuvre (TCM) through to the touch-down point at which the spacecraft comes to complete rest.
- The “feasibility” at the end of the “SCS” phase is quantified as follows:
  - ⇨ the spacecraft architecture is fixed, i.e. number and types of components such as heat shield(s), parachute(s), airbag(s), retro-rocket(s), landing-leg(s), etc., are known
  - ⇨ key spacecraft parameters (initial mass, volume, ballistic profile, etc.) with impact on GNC during EDL are known ± X%
  - ⇨ mission profile (initial velocity, entry angle, heat flux and attitude rates during entry, release point for heat shield, deployment point(s) for parachute(s), firing points/durations for retro-rockets., landing altitude, landing dispersion, impact velocity, etc.) is known ± X%
  - ⇨ figures of merit (delta v, peak acceleration and temperature, fuel consumption, etc.) are known ± X%
  - ⇨ environmental constraints (e.g. maximum winds, minimum visibility, etc) are known
  - ⇨ GNC concept (number of sensors/cameras, algorithms, etc.) is known
- Features
  - ⇨ Compatible with CDF
  - ⇨ Linear Models used in Design Trade-offs
  - ⇨ >> Real Time
  - ⇨ Parametric Analysis
  - ⇨ Covariance Analysis

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Mission Performance Simulator

- In a desktop environment
  - ⇨ iteratively refine the model of spacecraft and environment, as developed in the SCS phase, to provide a stable GNC architecture.
- The "stable GNC architecture" at the end of the "MPS" phase is quantified as follows:
  - ⇨ reference start conditions (mass of each spacecraft body, initial velocity and trajectory, etc) and limits for their deviation are known
  - ⇨ number and type of GNC sensors/actuators is fixed
  - ⇨ sampling rate for GNC sensors and refresh rates for GNC actuators are fixed.
  - ⇨ GNC algorithms are finalised
  - ⇨ robustness constraints (e.g. number and nature of tolerated sensor/actuator failures, etc) are established
- On the basis of the GNC architecture:
  - ⇨ simulation results provide best and worst case mission profiles (initial velocity, entry angle, heat flux and attitude rates during entry, release point for heat shield, deployment point(s) for parachute(s), firing points/durations for retro-rockets., landing altitude, landing dispersion, impact velocity, etc.)
  - ⇨ figures of merit (delta v, peak acceleration and temperature, fuel consumption, etc.) for best and worst case mission profiles are calculated.
- Features
  - ⇨ Natural Evolution from System Concept Simulator
  - ⇨ 6-DoF Multiple Body
  - ⇨ GNC, Trade-off
  - ⇨ Monte Carlo Analysis

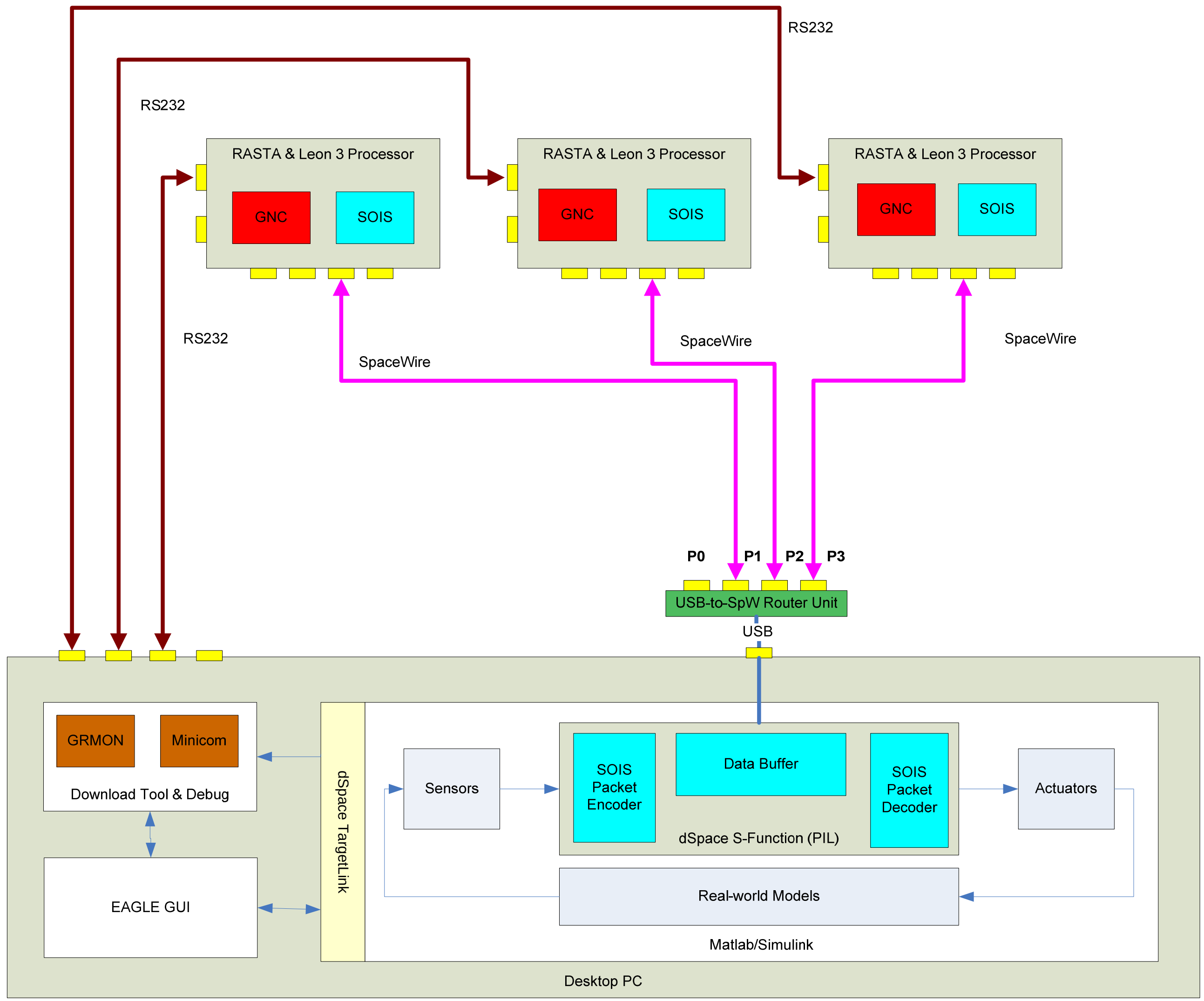
Non Real Time Functional Engineering Simulator

- In a desktop environment
  - ⇨ iteratively refine the model of spacecraft and environment, as developed in the MPS phase, to provide Robust GNC algorithms.
- The “robust GNC algorithms” at the end of the “NRT-FES” phase is determined by:
  - ⇨ For a selected scenarios perform in-depth analyses
  - ⇨ For specific mission intervals and/or for specific spacecraft components in order to confirm the mission viability.
  - ⇨ The principle areas that have been identified for in-depth analysis are:
    - Airbag deployment
    - Parachute deployment
    - Descent Landing leg deployment
    - Confirm GNC robustness in a full fidelity system simulation
- Features
  - ⇨ Natural Evolution from Mission Performance Simulator
  - ⇨ GNC Robustness testing
  - ⇨ Automatic Code Generation

Avionics Test Bed

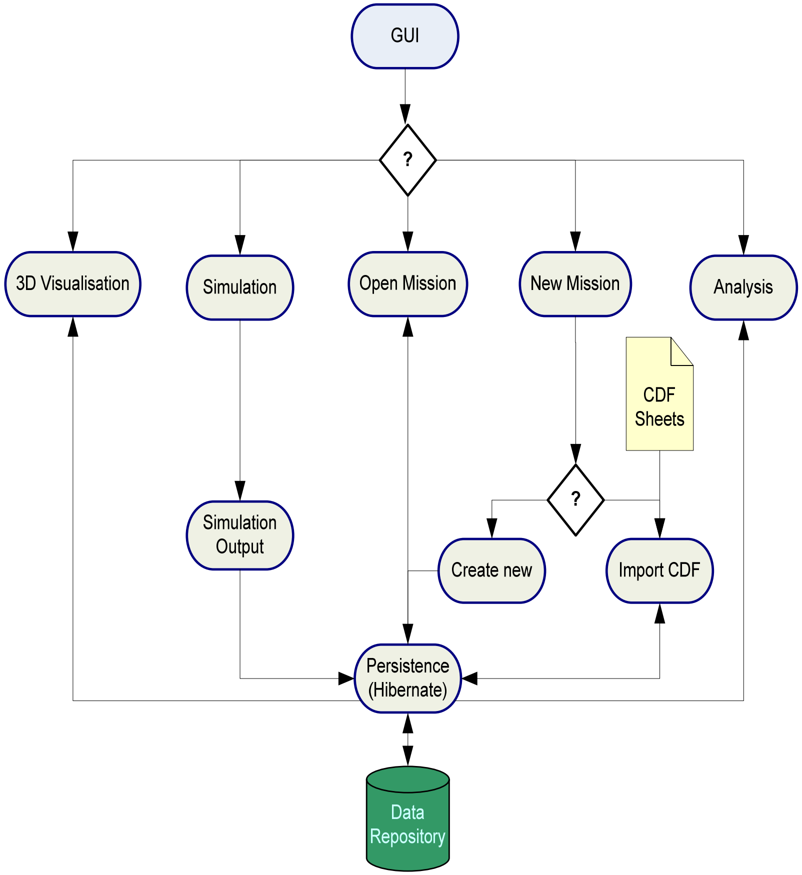
- Provide real-time end-to-end simulation of an EDL mission by:
  - ⇨ Generating target code for the GNC algorithms.
  - ⇨ Executing the generated target code under real time conditions by executing it on a representative flight hardware (incl. runtime system) that interacts via its I/O bus(ses) with the MPS level simulation of the GNC sensors/actuators and their environment
- Features
  - ⇨ Real time simulator, with hardware in the loop.
  - ⇨ TargetLink Based.
  - ⇨ SpaceWire and SOIS
  - ⇨ Run directly from Simulink
  - ⇨ Managed by GUI

Avionics Test Bed Architecture



Graphical User Interface

- Java based GUI built using Eclipse
- Uses JNI to Matlab to load data to/from Matlab and control simulations.
- Connects to Model and Data repositories, may be file system or SQL based.
- User interface based on buttons and drop menus to minimise input errors and ease of use.
- Java chosen due to portability (windows, linux, unix) and flexibility to connect to various systems.



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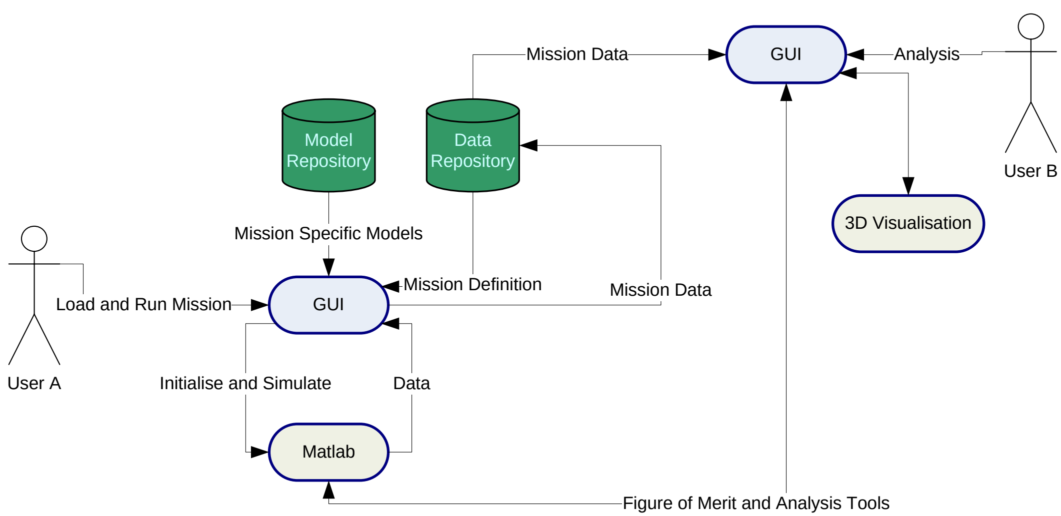
Data and Model Repositories

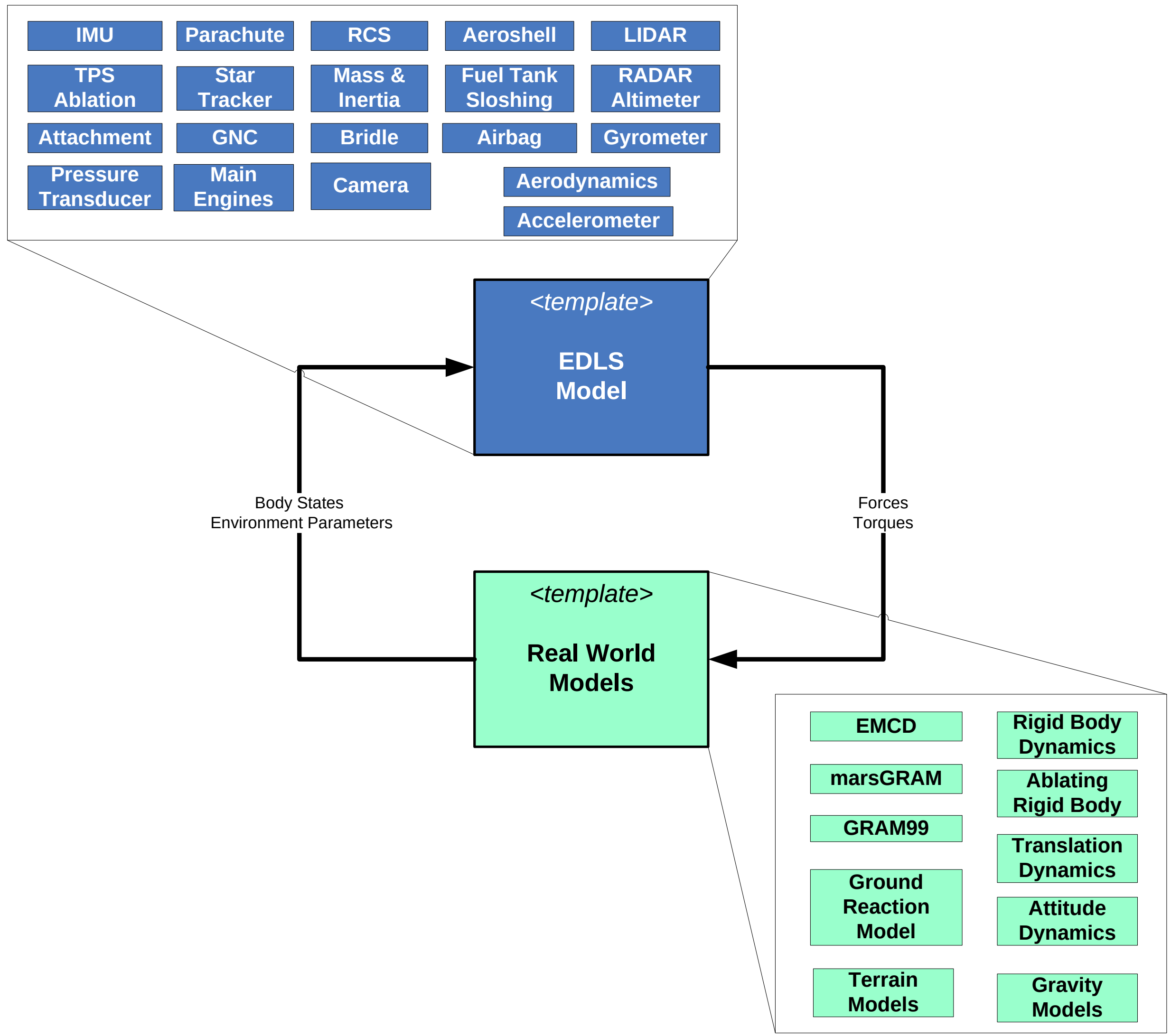
- Model Repository
  - ⇨ Is a configuration management and storage system for models.
  - ⇨ Can be an SQL database or directory on PC/Server (scaleable)
  - ⇨ Provides users with 2 streams:
    - Completed useable models (Release)
    - New model developments (Development)
- Data Repository
  - ⇨ Contains mission, system and model configuration data specific to a mission.
  - ⇨ Configuration management system
  - ⇨ Contains result data for analysis from a particular mission and system configuration.



Reference Missions

Type	Hypersonic Phase					Subsonic Parachute		Touchdown			Precision Landing and Hazard Avoidance	Powered Terminal Descent	Mission Type
	Ballistic	Lift and Drag						Airbags		Legs			
		Bank Angle		Angle of Attack									
		Constant	Modulated	Constant	Modulated	Uncontrolle d	Controlled	Non-vented	Vented				
M1	Yes	No	No	No	No	Yes	No	Yes*	No	No	No	Yes	Pathfinder
M2 a	Yes	No	No	No	No	Yes	No	Yes	No	No	No	No	MER
M2 b	Yes	No	No	No	No	Yes	No	No	Yes	No	No	Yes	ExoMars
M3	No	No	Yes	No	Yes	No	Yes	No	No	Yes*	Yes	Yes	MSR@Mars
E1	Yes	No	No	No	No	No	No	No	No	Yes	Yes	Yes	EVD
L1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes*	Yes	Yes	Surveyor

Mission Templates



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Target Users

- GNC Engineers
  - ⇨ Algorithms prototyping, maturing TRL, hardware testing.
- System Engineers/Designers
  - ⇨ Equipment choices, trade-off studies, performance analysis.
- Mission Engineers/Designers
  - ⇨ Mission concept, multiple system interactions, task optimisation.
- Test and Analysis Teams
  - ⇨ Validation and verification
- Allows users with domain specific knowledge to focus on specialist area.
- Provides an integration and test environment for the model, system and mission levels.
- Faster design iteration and increased productivity!

Summary

- From initial concept to hardware in the loop testing.
- From start of mission to end of mission
  - ⇨ no need to break analysis into sections.
- Physics based simulation
  - ⇨ Allows modelling of virtually any system.
- Multiple Fidelity
  - ⇨ Mix and match models to meet simulation needs.
- Based on open source and COTS products
  - ⇨ Eclipse
  - ⇨ Matlab
  - ⇨ TargetLink
- Open extensible architecture.

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Questions

Thanks!