



Rolls-Royce

PPEM015 - Ultra-compact intelligent electrical networks

SEAS DTC Conference 2009

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Overview

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- | Background context
- | Autonomous Power Management System
- | System Architecture
- | Planning
- | Future directions
- | Summary

Background Context

- | UxVs participate in increasingly complex missions
- | As technology develops, UxVs will enjoy greater degrees of autonomy
- | It will be necessary to control power generation and consumption across the platform in an intelligent manner
- | Overall mission goals are satisfied without compromising the safety and integrity of the system

Autonomous PMS – Aims

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- | Adherence to mission goals
 - | Manage power to meet mission criteria
- | Power consumption optimisation
 - | Efficient power allocation to improve platform capability and operational life
- | Adaptive power allocation
 - | Dynamically change power allocation policy to balance current and future requirements

Autonomous PMS - Challenges

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- | Operate under uncertainty
 - | Should handle unforeseen situations
- | Prioritise decisions
 - | Power allocation across sub-systems should be prioritised
- | Decision making in (or close to) real-time
 - | Alternative power allocation policy should be generated without much latency

Autonomous PMS – Solution

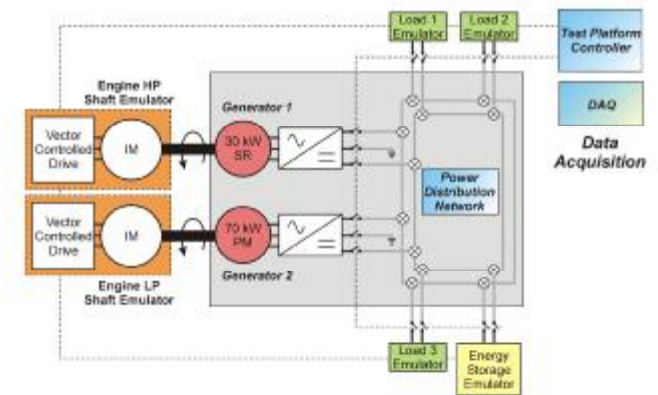
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- | Agent technology to model PM decision-making
 - | Software with (controlled) autonomy
 - | Goal driven and adaptive
 - | Multi-agent society with loosely-coupled interactions
 - | Encapsulation of domain knowledge expertise
 - | Use a layered architecture on the IEPNEF hardware

- | Virtual UAV
 - | power characteristics modelled in software
 - | real-time behaviour played out on the IEPNEF hardware

Evaluation and Validation

- Intelligent Electrical Power Network Evaluation Facility (IEPNEF)
- Interface physical hardware of IEPNEF with Agent-based software system, which:
 - Generates plans for UxV mission
 - Monitors IEPNEF asset status
 - Controls IEPNEF to meet mission objectives with efficient power allocation

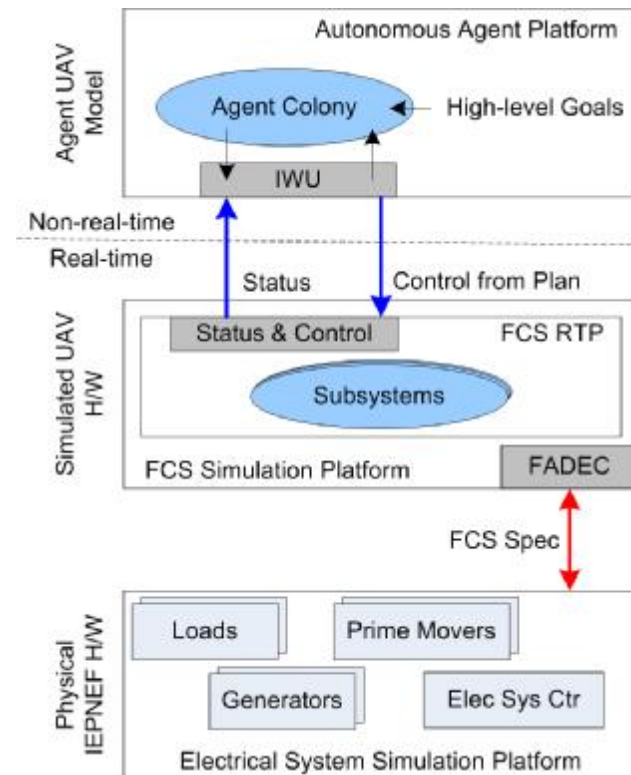


Overall Architecture

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3-layer mixed hardware-software system

- Software application platform
 - Agents
 - Plan to optimise power allocation
- Flight control system platform
 - Measure and control the physical IEPNEF hardware
- Electrical system simulation platform
 - IEPNEF hardware



Agent System Architecture

Active Decision Makers

Goal Planner

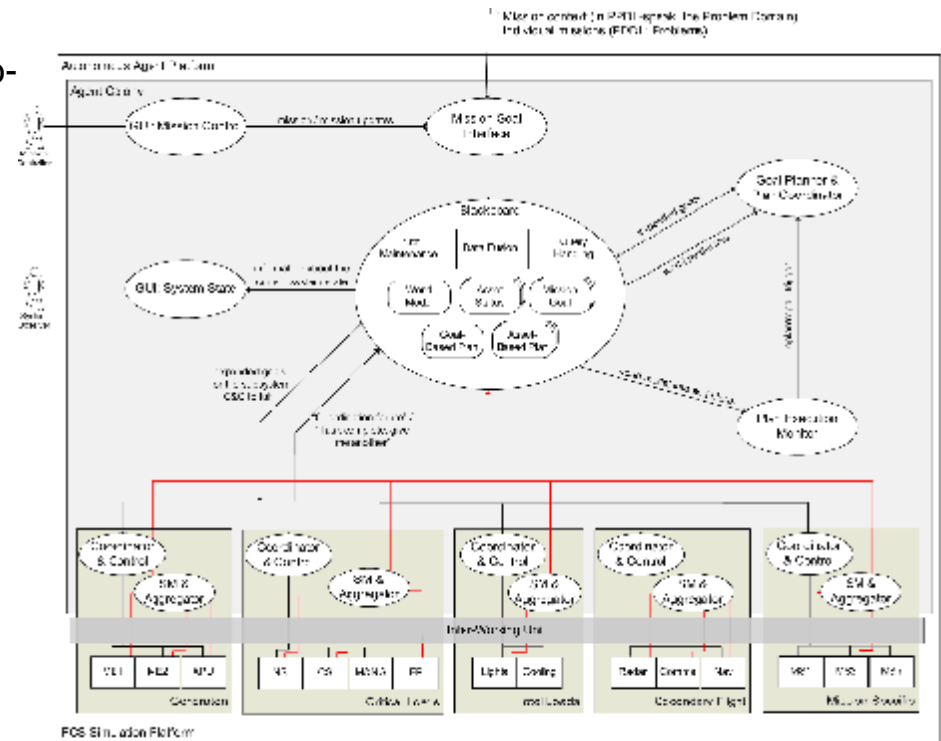
- Process high-level vignette description into sub-goals and plans (sub-tasks)
- Delegates sub-tasks to Asset Coordinators

Asset Coordinators

- Process sub-goals into executable tasks or control actions
- Resolves conflicts in power allocation between load systems
- Liaise with Status monitors

Asset Status Monitor

- Reads status data off physical platform
- Informs Asset coordinators



Agent System Architecture (2)

Planning Enablers & Support

Plan Execution Monitor

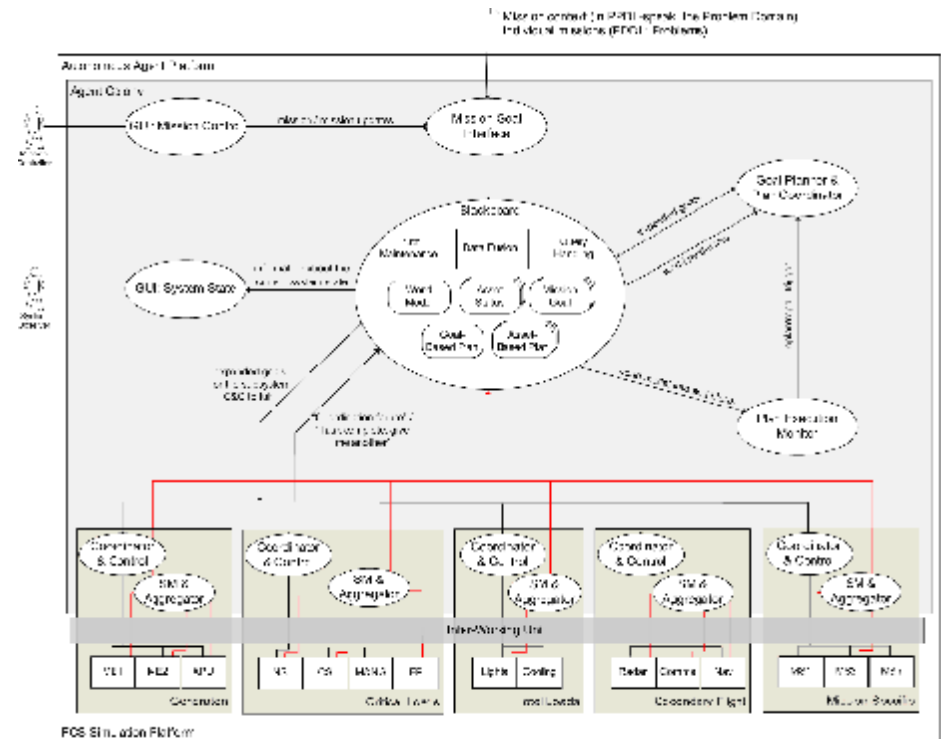
- Checks progress and validity of plan in light of new events unfolding
- Triggers new planning activity in Goal Planner

Blackboard

- Active information repository
 - World model, Knowledge repository
- Agents read and write data
- Truth maintenance

Output Agent

- User Interface for mission control and status display



Mission Contexts

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- | Based on SEAS DTC vignettes

- | Informing choices about
 - | Loads and generators to simulate
 - | Storyline to demonstrate plan generation and execution

- | Vignettes selected:
 - | Vignette 3A: Peace enforcement (Urban patrol)
 - | Vignette 8: Air attack (and ISTAR chain)

Mission Task Requirements

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- | Specification of:
 - | Typical tasks/actions undertaken by UAV during a mission
 - start, taxi, take-off, climb, cruise, etc.
 - | Parameter specification in each task
 - thrust, altitude, power consumed, etc.
 - | List of active loads during each task

- | The tasks will be generated by planner agent from high-level mission description

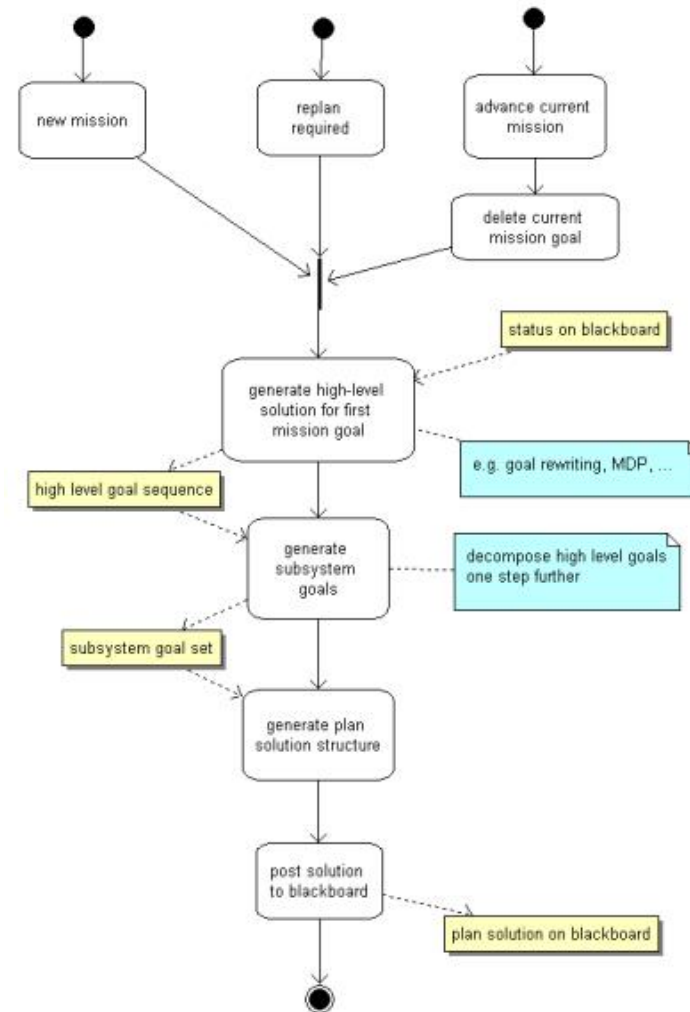
Mission Planning

- | Main planning stages:
 - | High-level:
 - Plan generation and delegation of sub-plans
 - | Coordinator level:
 - Creation of sub-tasks and delegation of platform-level tasks
 - Manage resource conflicts and contingencies
 - | Platform level:
 - Execute tasks

- | Plan monitoring and re-planning
 - | Monitor asset status, environment, and planning progress to trigger plan adaptation

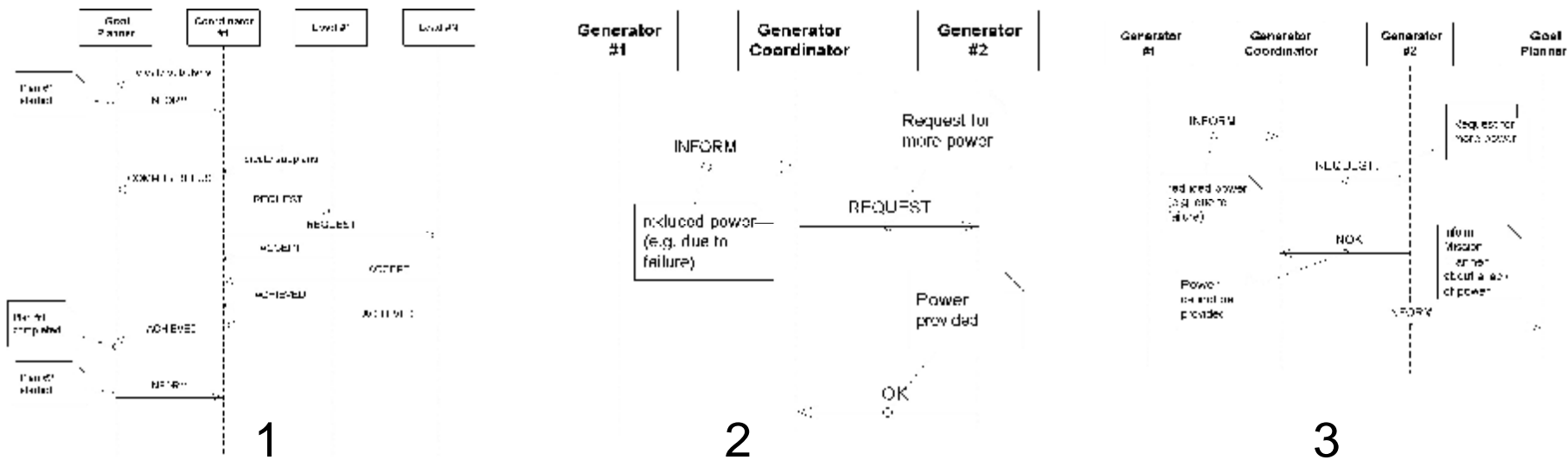
High-level Planning

- | High-Level Goal Planning
 - | Takes Mission Tasks
 - | Generates tasks for the Coordinator agents
- | Goal refinement by two decomposition steps
 - | Mission tasks \rightarrow high-level goals
 - | High-level goals \rightarrow subsystem goals
- | Options for achieving goal decomposition
 - | Rule-based goal rewriting
 - | Markov Decision Processes
- | Planning horizons are enforced
 - | Don't plan too far ahead, the world is always changing



Coordinator-level Planning

- | Coordinators task individual assets
 - | negotiates how the asset mix fulfils the tasks set to it (1)
- | Assets may fail to deliver
 - | either managed locally (2)
 - | or delegated upwards (3)



Platform-level Planning

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- | The Autonomous Agent Platform receives mission goals and translates these into executable tasks

- | Tasks are executed on a UAV model as perceived by the Autonomous Agent Platform
 - | Execution occurs in the Flight Control Simulator
 - | This then controls the loads and generators of the IEPNEF hardware

- | The Autonomous Agent Platform does not know the details of the underlying IEPNEF facility hardware

Plan Monitoring & Re-planning

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- | Blackboard
 - | Central information store
 - | Provides the world over which the planner reasons

- | Status monitoring
 - | Assets status info is monitored and placed on blackboard

- | Plan monitoring
 - | Continually compares reality vs plan expectation

- | Re-planning strategies
 - | Monitoring identifies where & when the plan is failing
 - | Re-planning / plan repair works around this to get the system back on track

Ongoing Activities

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- | Agent architecture delivered on time
- | Good progress in the software design
- | Regular feedback to acquire representative load models to be integrated within the agent platform

Future Directions

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- | Develop agent platform
- | Develop / acquire representative load models
- | Demonstrate in simulation mission planning using simulated load models
- | Integrate agent platform for real-time demonstration of mission planning on IEPNEF