



PPEM016

Intelligent Power Management for Autonomous Vehicles

Work Package 4: Architecture Study

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Work Package 4: IPM Architecture Study

Goal: to develop a generic and scalable IPM architecture solution

Requirements and components identified from:

- ADD020: Concepts and Options for Power Management on Autonomous Vehicles
- IF058: Semantics for Power Management
- IF061: Investigation into the Interaction Between Automatic and Autonomous Systems
- PPEM013: Autonomous Soaring
- IF059: Multiplanner

Design options for components of architecture considered

Assumptions



The architectural design of the power management system assumes the following:

Guided by power management system usage in a specific example mission

A representative vignette which can be undertaken by ground or air autonomous vehicles

The mission is overseen by a human operator, who will give the mission to the UV and can make an appropriate response, if necessary

Functions Required for IPM



Mission planner

- Provides the planning functionality
- Considers goals that need to be achieved in a given situation
- Planner works in conjunction with a Plan Execution Monitor

Power management

- Monitors the power resources and requirements of an asset
- Controls the behaviour of the asset

Communication mechanism

- Information flow within and between actors

Communication language

- Semantic translation of information between actors

Architectural Components



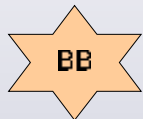
Planner

- Implements the planning functionality, including plan execution monitoring
- Reasons over information on the blackboard



Asset handling

- Real or virtual asset being controlled
- Power source, consumer, or store
- Decompose into monitoring and control functions



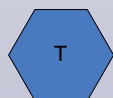
Blackboard

- Read / write knowledge base
- Stores the world model
- Performs truth maintenance



Asset monitor

- Interface for asset status information
- Semantic translator handles abstraction



Semantic translation

- Extracts the meaningful information from raw data
- Converts plans into control sequences



Asset Controller

- Executes control sequences
- Semantic translator handles plan conversion

Design Options for Components

Planning options (3):

- Single local planner
- Multiple planners distributed with coordination
- Multiple planners distributed without coordination

Blackboard options (2):

- Central (single logical function)
- Local (several independent blackboards)

Semantic translation options (4):

- Implicit or explicit
- Central or distributed

Asset handling (2 options):

- Monolithic
- Distributed

Architectures



If the design options for components were completely independent:

- $2 \times 2 \times 4 \times 3 = 48$ potential architectures

Analysis reduces the options:

- some architectural options are mutually exclusive (e.g. cannot have distribution in a monolithic architecture)
- explicit translation recommended in IF058
- full derivation at the end of the presentation

Final outcome:

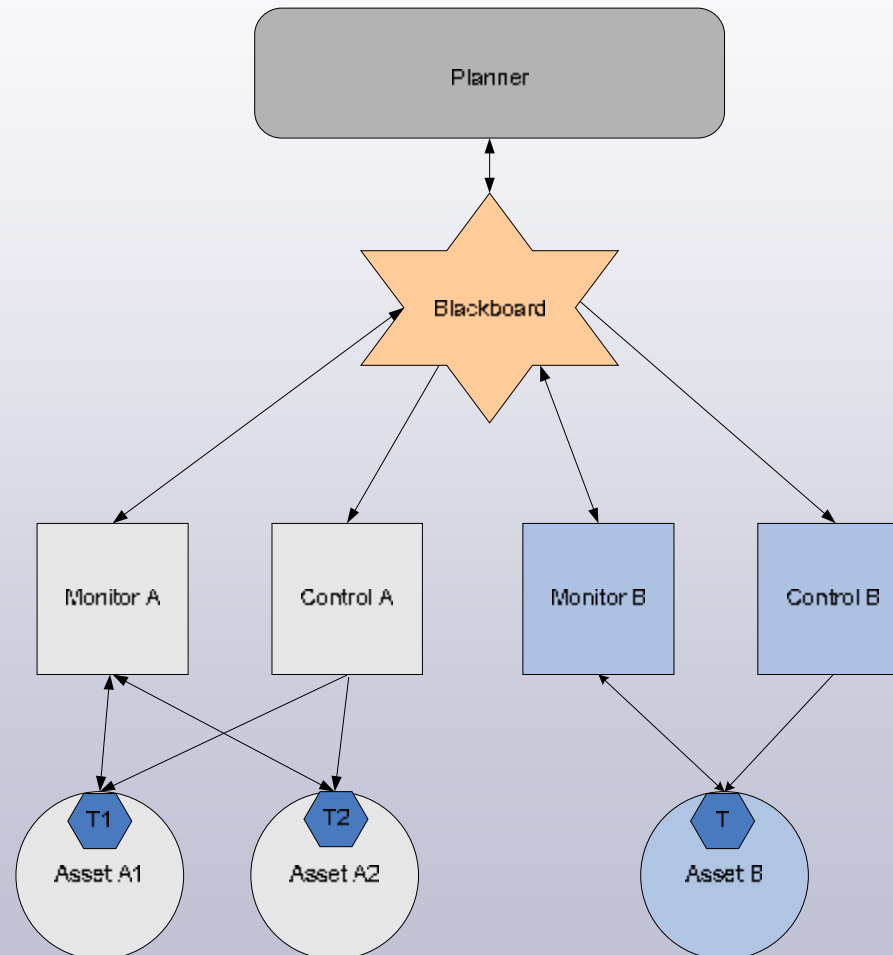
- five feasible architectures identified from the 48
- downselected to the two options presented here

Single Planner, Central Blackboard, Distributed Semantic Translation



- Distributed asset control
- Central blackboard
- Distributed translation
- Single planner

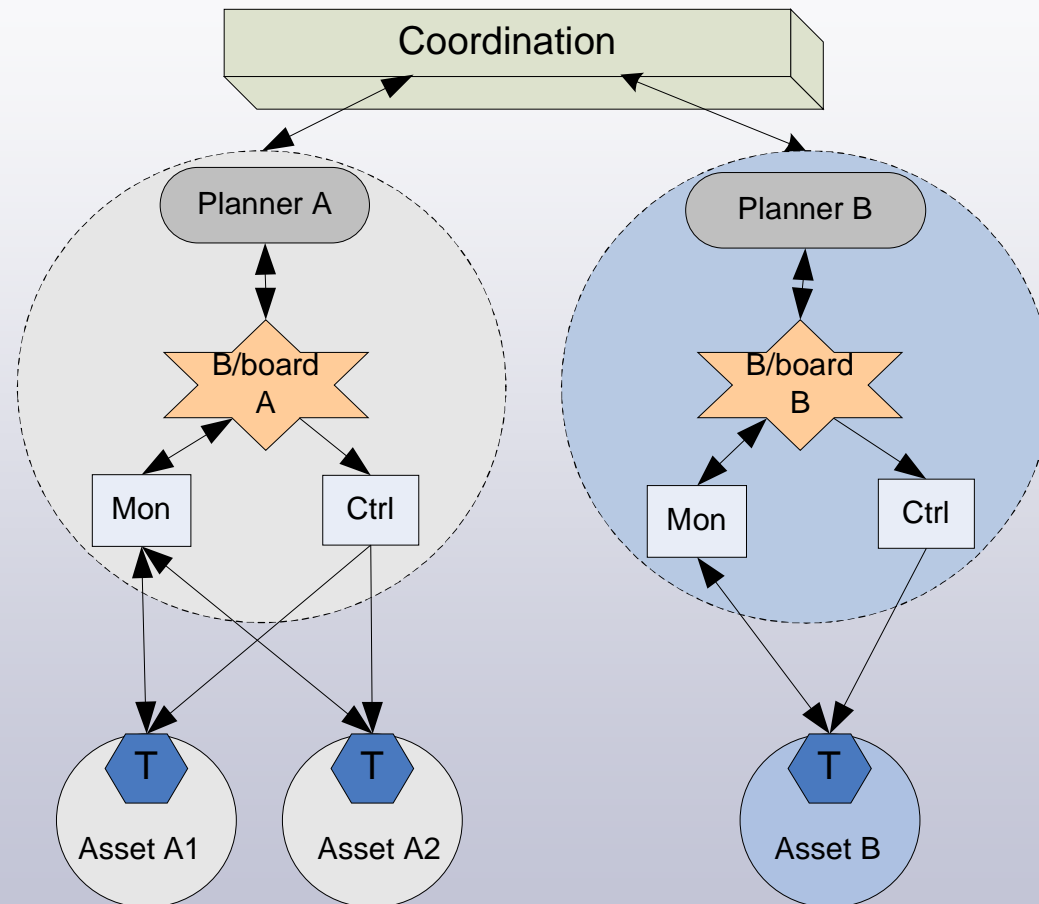
- Decouples planning from detailed asset management
- Scalable for new assets
- Simple efficient translation



Distributed Planning with Coordination



- Distributed asset control
- Local blackboards
- Distributed translation
- Distributed planner with coordination
- Coordination function is a high-level planner which generates goals to be devolved to subsidiary planners
- Scalable
- Simple efficient translation
- Subsidiarity and devolved autonomy



Observations and Proposal



Observations:

- Monolithic and centralised architectures are not scalable
- Highly distributed planning without coordination is interesting but complex and could have undesirable emergent effects

Proposed architecture – choice between:

- Single Planner, Central Blackboard, Distributed Semantic Translation
- Distributed planning with coordination

Discussion

Thank you!

**Supplementary slides on the derivation of the
initial down-selection
(48 options -> 5 -> 2)**

Reducing the Architectural Options



Started with $2 \times 2 \times 3 \times 4 = 48$ options

Semantic translation options:

- Explicit recommended so remove implicit options
- $48 \rightarrow 1 \times 24$

Power Management options:

- Monolithic implies all else is central
- $24 \rightarrow 12 + 1$

"12" decomposes into the remaining variables:

- Central or local blackboard (BC, BL)
- Central or distributed translation (TC, TD)
- Planner: single, several coordinated, several not coordinated (P1, PSC, PSNC)

Constraints:

- 1) More than one planner \Rightarrow local blackboards and distributed semantic translation
- 2) Local blackboards only makes sense when there is more than one planner

Enumerating the 12 possibilities:

- BC TC P1 = OK
- BC TC PSC = No (1)
- BC TC PSNC = No (1)
- BC TD P1 = OK
- BC TD PSC = No (1)
- BC TD PSNC = No (1)
- BL TC P1 = No (2)
- BL TC PSC = No (1)
- BL TC PSNC = No (1)
- BL TD P1 = No (2)
- BL TD PSC = OK
- BL TD PSNC = OK

Five remaining options:

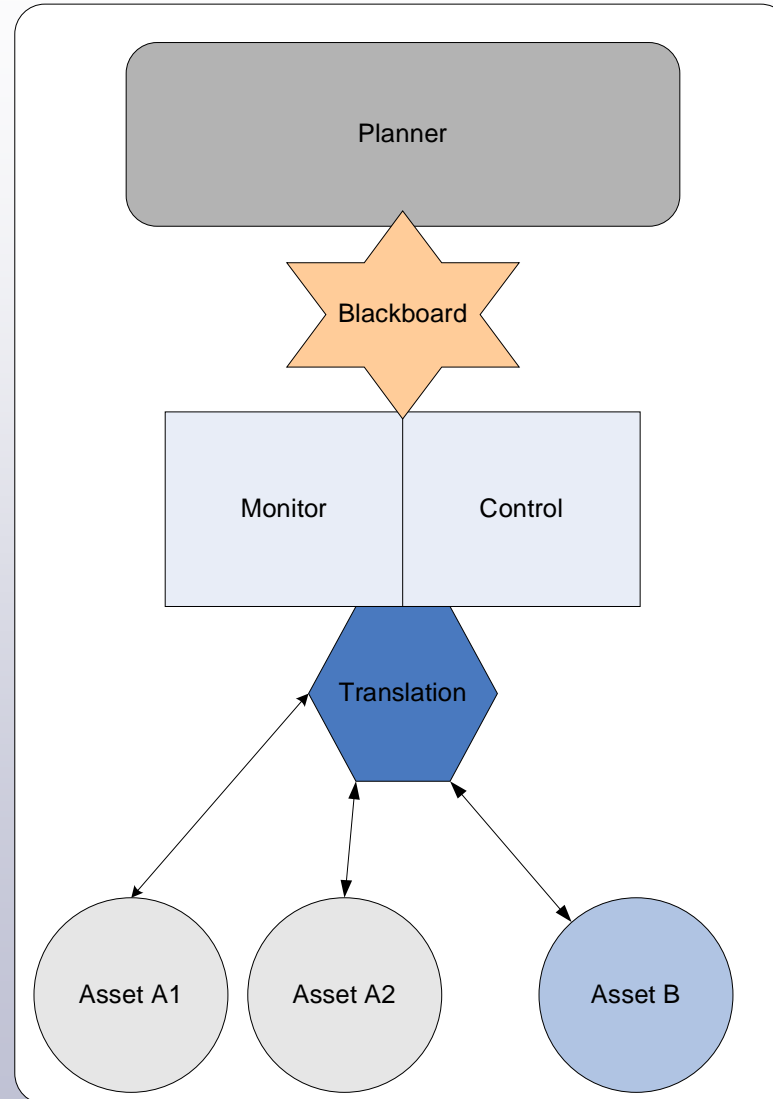
1. Monolithic
2. Single planner, central blackboard, central translation
3. Single planner, central blackboard, distributed translation
4. Distributed planning with coordination
5. Distributed planning without coordination

Downselected to options 3 and 4

Monolithic

- Monolithic asset control
- Central translation
- Central blackboard
- Single planner

- Complex
- Not easily scalable

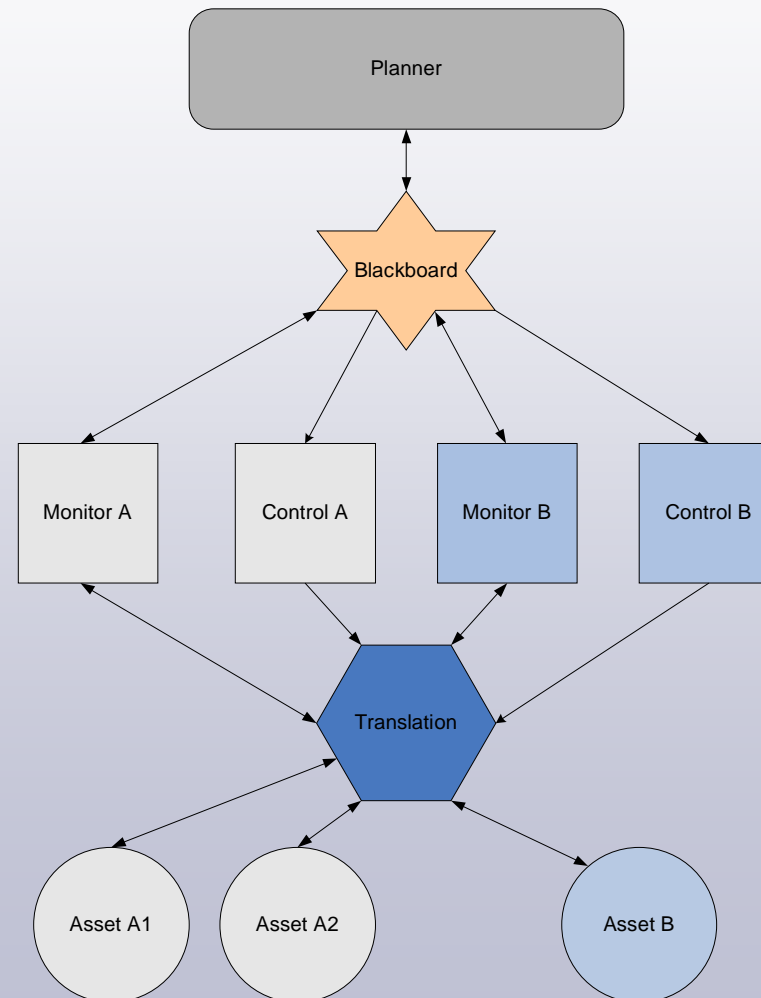


Single Planner, Central Blackboard, Central Semantic Translation



- Distributed asset control
- Central blackboard
- Central translation
- Single planner

- Decouples mission planner from power management
- Scalable for new assets



Distributed Planning without Coordination



- Distributed asset control
- Local blackboards
- Distributed translation
- Distributed planner (no coordination)
- Scalable
- Simple efficient translation
- Subsidiarity
- High probability of resource conflicts
- Emergent effects

