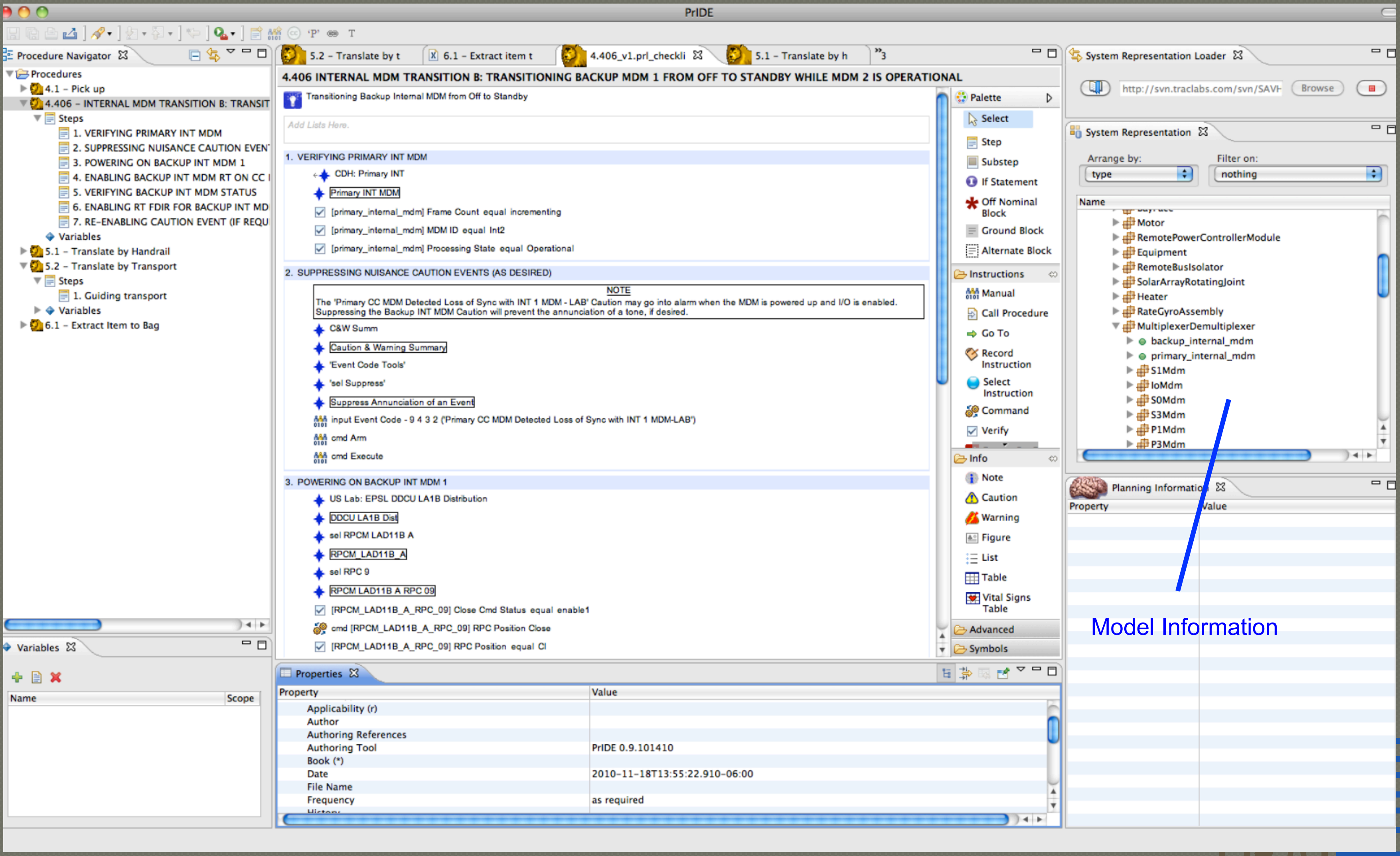
Ontological Models to Support Planning Operations

Pete Bonasso
Mark Boddy (Adventium)
Dave Kortenkamp
Scott Bell

Overview of the Project

- We have PRIDE & PRL for *procedure* authoring, display and execution
- We have augmented PRIDE & PRL to author & display *planning* information associated with procedures that can be used by automated planners
- The major stumbling block to realizing the widespread use of automation techniques for operations is *capturing and maintaining the domain models* needed to support such techniques
- This proposal seeks to develop a framework for consistent ontological modeling across domains, that can be exploited by planners and executives currently being developed for NASA

Procedure Authoring System (PRIDE)



Procedures
- 4.1 – Pick up
- 4.406 – INTERNAL MDM TRANSITION B: TRANSIT
  - Steps
    - 1. VERIFYING PRIMARY INT MDM
    - 2. SUPPRESSING NUISANCE CAUTION EVEN
    - 3. POWERING ON BACKUP INT MDM 1
    - 4. ENABLING BACKUP INT MDM RT ON CC I
    - 5. VERIFYING BACKUP INT MDM STATUS
    - 6. ENABLING RT FDIR FOR BACKUP INT MD
    - 7. RE-ENABLING CAUTION EVENT (IF REQU
  - Variables
- 5.1 – Translate by Handrail
- 5.2 – Translate by Transport
  - Steps
    - 1. Guiding transport
  - Variables
- 6.1 – Extract Item to Bag

5.2 – Translate by t | 6.1 – Extract item t | 4.406_v1.prl_checkli | 5.1 – Translate by h | »3

4.406 INTERNAL MDM TRANSITION B: TRANSITIONING BACKUP MDM 1 FROM OFF TO STANDBY WHILE MDM 2 IS OPERATIONAL

Transitioning Backup Internal MDM from Off to Standby

Add Lists Here.

1. VERIFYING PRIMARY INT MDM

CDH: Primary INT

Primary INT MDM

☑ [primary_internal_mdm] Frame Count equal incrementing

☑ [primary_internal_mdm] MDM ID equal Int2

☑ [primary_internal_mdm] Processing State equal Operational

2. SUPPRESSING NUISANCE CAUTION EVENTS (AS DESIRED)

NOTE

The 'Primary CC MDM Detected Loss of Sync with INT 1 MDM - LAB' Caution may go into alarm when the MDM is powered up and I/O is enabled. Suppressing the Backup INT MDM Caution will prevent the annunciation of a tone, if desired.

C&W Summ

Caution & Warning Summary

'Event Code Tools'

'sel Suppress'

Suppress Annunciation of an Event

input Event Code - 9 4 3 2 ('Primary CC MDM Detected Loss of Sync with INT 1 MDM-LAB')

cmd Arm

cmd Execute

3. POWERING ON BACKUP INT MDM 1

US Lab: EPSL DDCU LA1B Distribution

DDCU LA1B Dist

sel RPCM LAD11B A

RPCM_LAD11B_A

sel RPC 9

RPCM LAD11B A RPC 09

☑ [RPCM_LAD11B_A_RPC_09] Close Cmd Status equal enable1

cmd [RPCM_LAD11B_A_RPC_09] RPC Position Close

☑ [RPCM_LAD11B_A_RPC_09] RPC Position equal Cl

Property	Value
Applicability (r)	
Author	
Authoring References	
Authoring Tool	PrIDE 0.9.101410
Book (*)	
Date	2010-11-18T13:55:22.910-06:00
File Name	
Frequency	as required

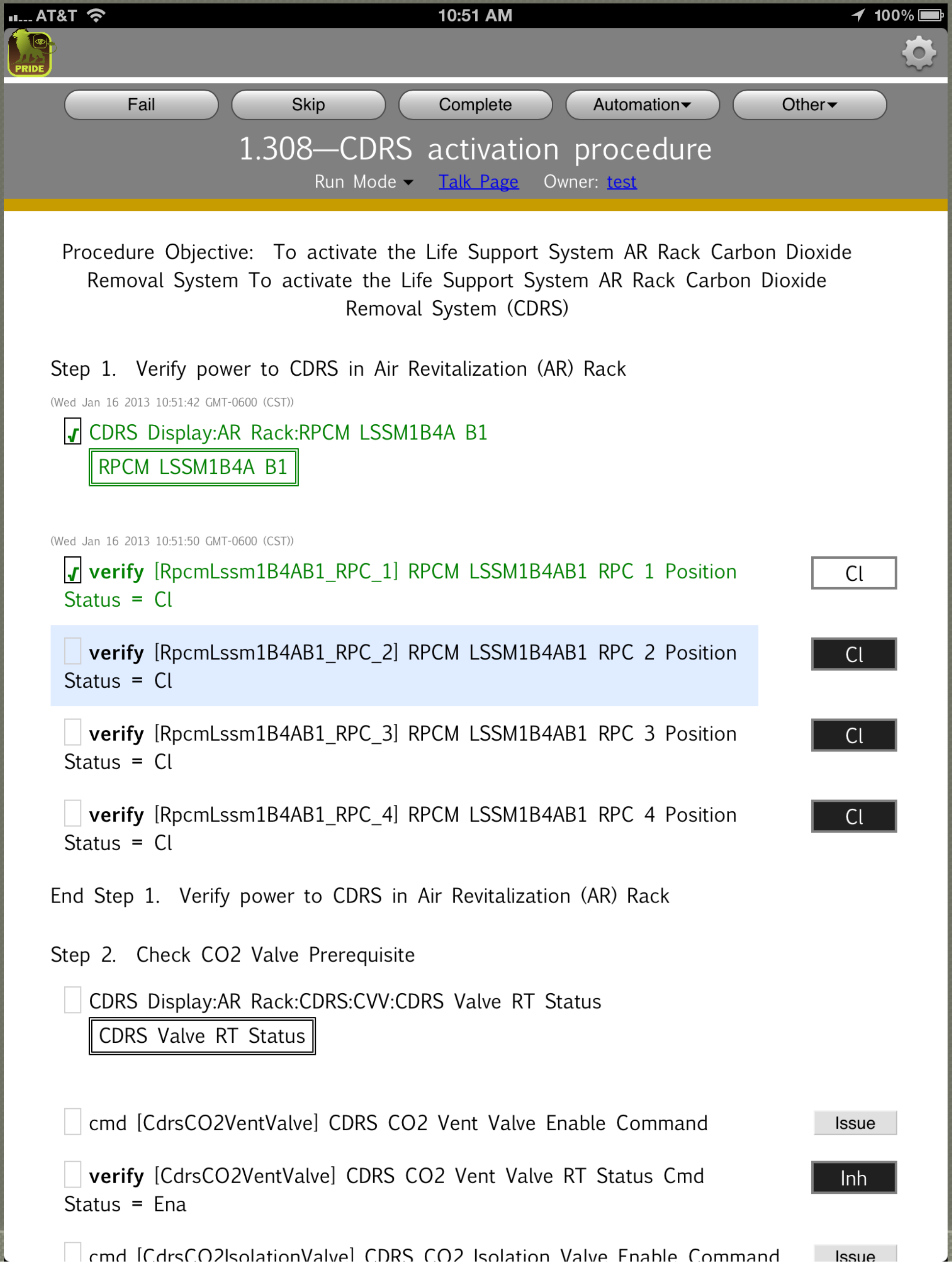
Name	Scope

Name
- Motor
- RemotePowerControllerModule
- Equipment
- RemoteBusIsolator
- SolarArrayRotatingJoint
- Heater
- RateGyroAssembly
- MultiplexerDemultiplexer
  - backup_internal_mdm
  - primary_internal_mdm
  - S1Mdm
  - IoMdm
  - S0Mdm
  - S3Mdm
  - P1Mdm
  - P3Mdm

Property	Value

Output is in an XML schema called Procedure Representation Language (PRL)

PRIDE Viewer and Executor



1.308—CDRS activation procedure

Procedure Objective: To activate the Life Support System AR Rack Carbon Dioxide Removal System To activate the Life Support System AR Rack Carbon Dioxide Removal System (CDRS)

Step 1. Verify power to CDRS in Air Revitalization (AR) Rack

(Wed Jan 16 2013 10:51:42 GMT-0600 (CST))

☑ CDRS Display:AR Rack:RPCM LSSM1B4A B1

RPCM LSSM1B4A B1

(Wed Jan 16 2013 10:51:50 GMT-0600 (CST))

☑ **verify** [RpcmLssm1B4AB1_RPC_1] RPCM LSSM1B4AB1 RPC 1 Position Status = Cl — Cl

☐ **verify** [RpcmLssm1B4AB1_RPC_2] RPCM LSSM1B4AB1 RPC 2 Position Status = Cl — Cl

☐ **verify** [RpcmLssm1B4AB1_RPC_3] RPCM LSSM1B4AB1 RPC 3 Position Status = Cl — Cl

☐ **verify** [RpcmLssm1B4AB1_RPC_4] RPCM LSSM1B4AB1 RPC 4 Position Status = Cl — Cl

End Step 1. Verify power to CDRS in Air Revitalization (AR) Rack

Step 2. Check CO2 Valve Prerequisite

☐ CDRS Display:AR Rack:CDRS:CVV:CDRS Valve RT Status

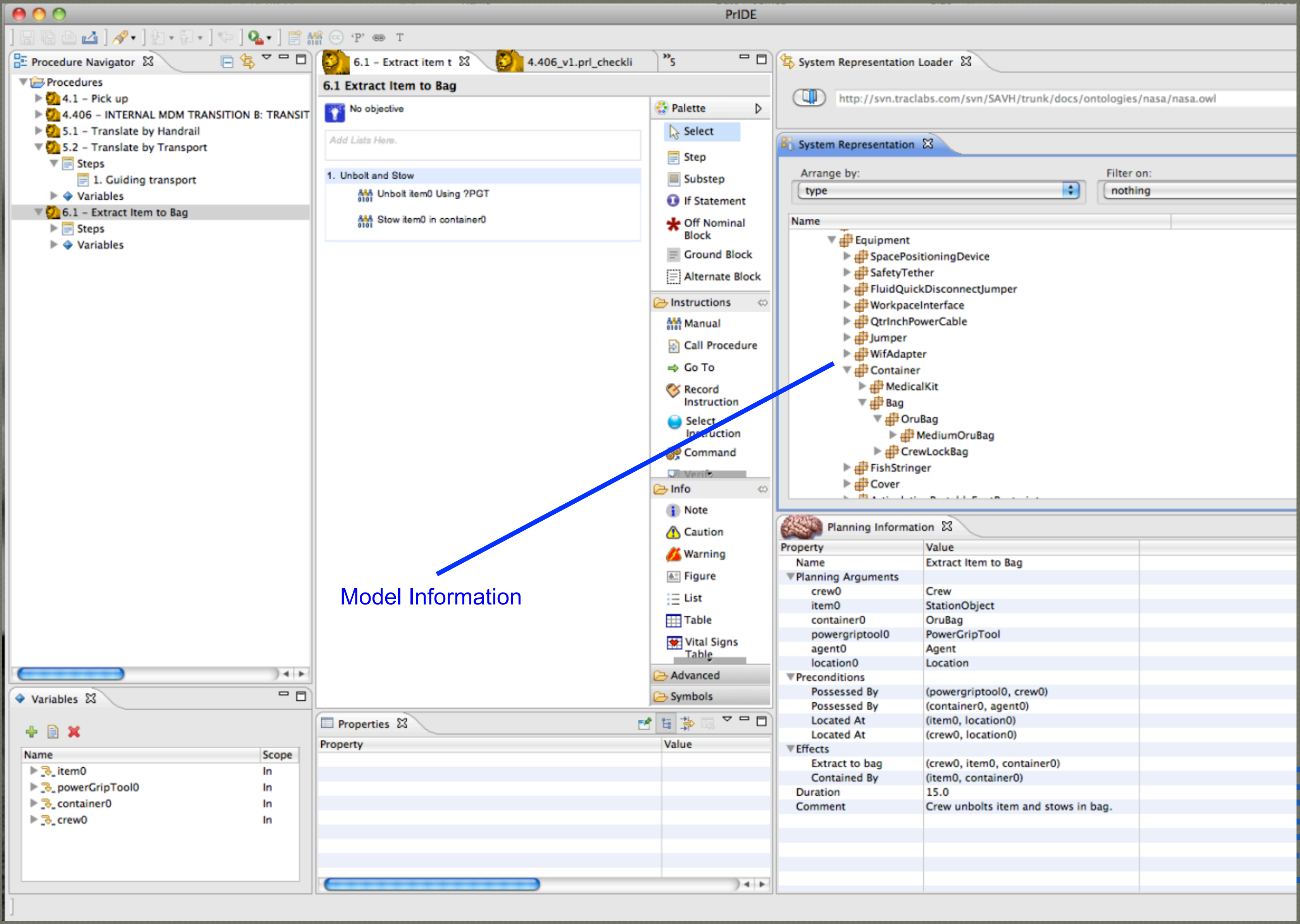
CDRS Valve RT Status

☐ cmd [CdrsCO2VentValve] CDRS CO2 Vent Valve Enable Command — Issue

☐ **verify** [CdrsCO2VentValve] CDRS CO2 Vent Valve RT Status Cmd Status = Ena — Inh

☐ cmd [CdrsCO2IsolationValve] CDRS CO2 Isolation Valve Enable Command — Issue

PRIDE Planning Wizard (PPW)



- Procedures
  - 4.1 - Pick up
  - 4.406 - INTERNAL MDM TRANSITION B: TRANSIT
  - 5.1 - Translate by Handrail
  - 5.2 - Translate by Transport
    - Steps
      - 1. Guiding transport
    - Variables
  - 6.1 - Extract Item to Bag
    - Steps
    - Variables

6.1 Extract Item to Bag

No objective

Add Lists Here.

1. Unbolt and Stow
   - Unbolt item0 Using ?PGT
   - Stow item0 in container0

http://svn.traclabs.com/svn/SAVH/trunk/docs/ontologies/nasa/nasa.owl

Arrange by: type

Filter on: nothing

Name

- Equipment
  - SpacePositioningDevice
  - SafetyTether
  - FluidQuickDisconnectJumper
  - WorkpaceInterface
  - QtrInchPowerCable
  - Jumper
  - WifAdapter
  - Container
    - MedicalKit
    - Bag
      - OruBag
        - MediumOruBag
      - CrewLockBag
  - FishStringer
  - Cover

Property	Value
Name	Extract Item to Bag
Planning Arguments	
crew0	Crew
item0	StationObject
container0	OruBag
powergriptool0	PowerGripTool
agent0	Agent
location0	Location
Preconditions	
Possessed By	(powergriptool0, crew0)
Possessed By	(container0, agent0)
Located At	(item0, location0)
Located At	(crew0, location0)
Effects	
Extract to bag	(crew0, item0, container0)
Contained By	(item0, container0)
Duration	15.0
Comment	Crew unbolts item and stows in bag.

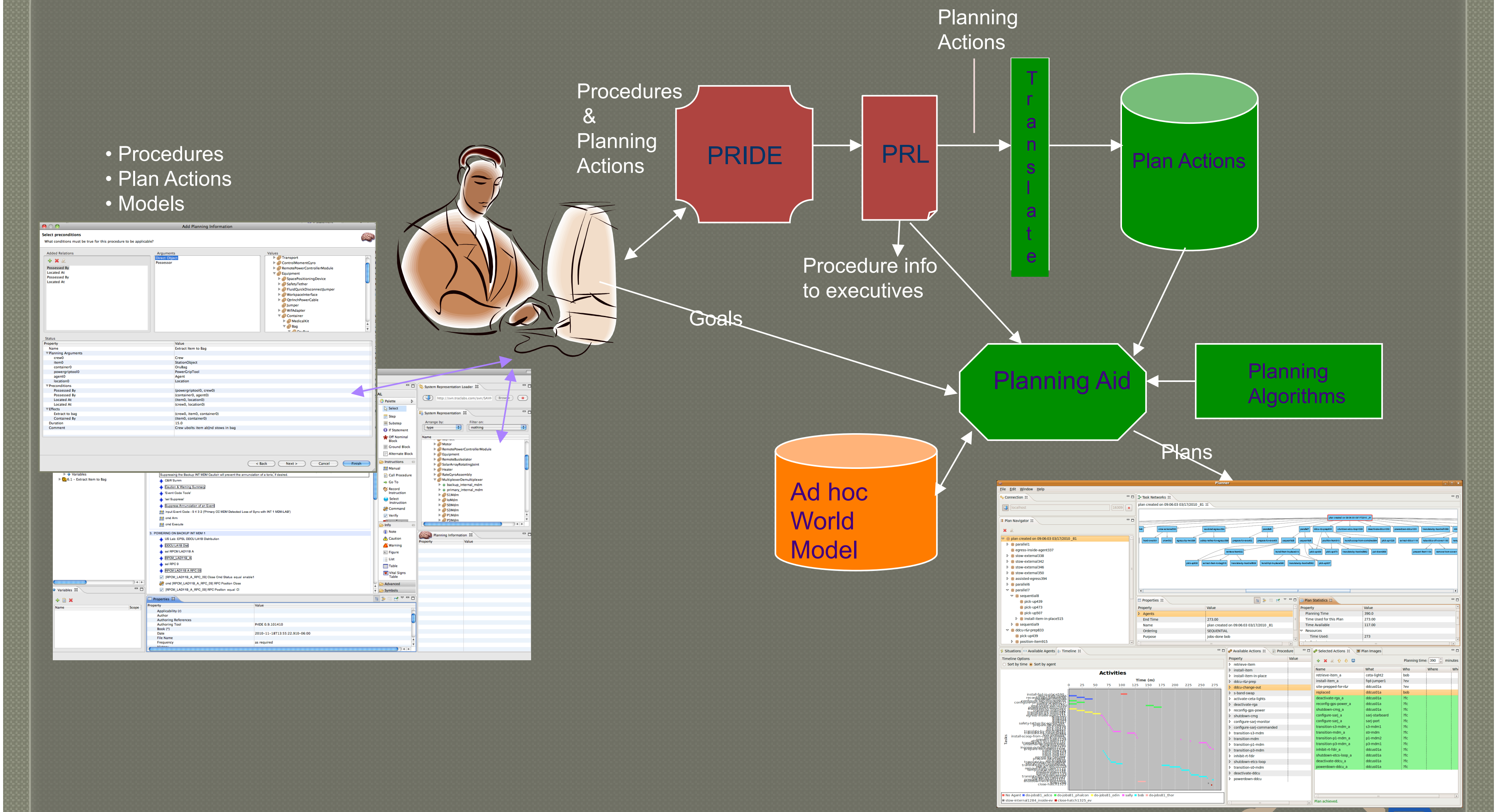
Name	Scope
item0	In
powerGripTool0	In
container0	In
crew0	In

Property	Value

Model Information

Planning Development Environment

- Procedures
- Plan Actions
- Models



Planning Actions

Procedures & Planning Actions

PRIDE

PRL

Translate

Plan Actions

Procedure info to executives

Goals

Planning Aid

Planning Algorithms

Ad hoc World Model

Plans

Add Planning Information

Select preconditions

What conditions must be true for this procedure to be applicable?

Added Relations: Possessed By, Located At, Possessed By, Located At

Arguments: Direct Object, Possessor

Values: Transport, ControlMomentGyro, RemotePowerControllerModule, Equipment, SpacePositioningDevice, SafetyTether, FluidQuickDisconnectJumper, WorkpaceInterface, QtrInchPowerCable, Jumper, WifAdapter, Container, MedicalKit, Bag

Status

Property	Value
Name	Extract Item to Bag
Planning Arguments	
crew0	Crew
item0	StationObject
container0	OruBag
powergriptool0	PowerGripTool
agent0	Agent
location0	Location
Preconditions	
Possessed By	(powergriptool0, crew0)
Possessed By	(container0, agent0)
Located At	(item0, location0)
Located At	(crew0, location0)
Effects	
Extract to bag	(crew0, item0, container0)
Contained By	(item0, container0)
Duration	15.0
Comment	Crew ubolts item ab]nd stows in bag

< Back | Next > | Cancel | Finish

6.1 – Extract Item to Bag

Suppressing the Backup INT MDM Caution will prevent the annunciation of a tone, if desired.

C&W Summ

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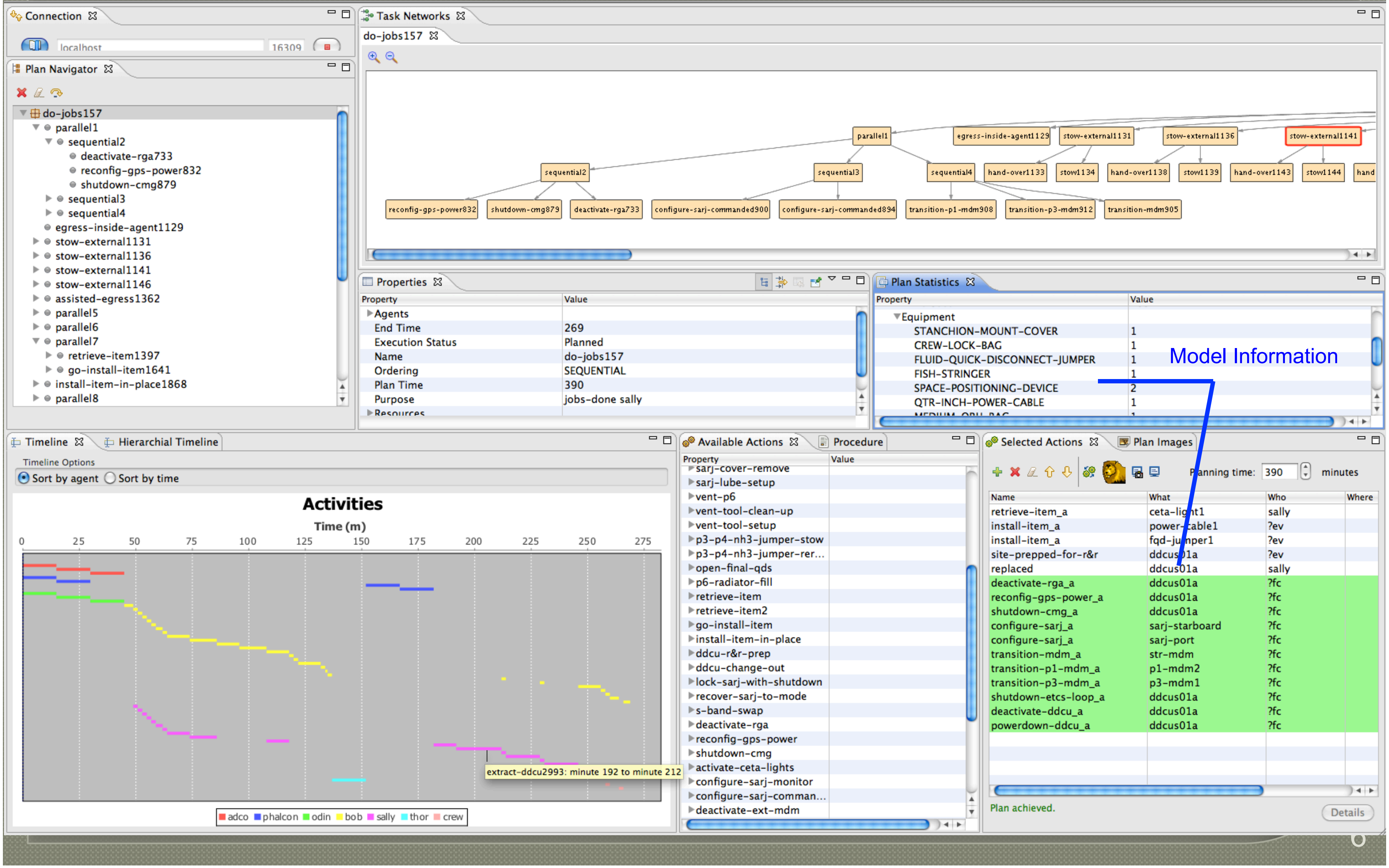
cmd Execute

3. POWERING ON BACKUP INT MDM 1

Interactive Plan Generation System



Connection ☒

localhost 16309

Plan Navigator ☒

- do-jobs157
  - parallel1
    - sequential2
      - deactivate-rga733
      - reconfig-gps-power832
      - shutdown-cmg879
    - sequential3
    - sequential4
  - egress-inside-agent1129
  - stow-external1131
  - stow-external1136
  - stow-external1141
  - stow-external1146
  - assisted-egress1362
  - parallel5
  - parallel6
  - parallel7
    - retrieve-item1397
    - go-install-item1641
  - install-item-in-place1868
  - parallel8

Task Networks ☒

do-jobs157 ☒

Properties ☒

Property	Value
Agents	
End Time	269
Execution Status	Planned
Name	do-jobs157
Ordering	SEQUENTIAL
Plan Time	390
Purpose	jobs-done sally
Resources	

Plan Statistics ☒

Property	Value
Equipment	
STANCHION-MOUNT-COVER	1
CREW-LOCK-BAG	1
FLUID-QUICK-DISCONNECT-JUMPER	1
FISH-STRINGER	1
SPACE-POSITIONING-DEVICE	2
QTR-INCH-POWER-CABLE	1
MEDIUM-ORU-BAG	1

Model Information

Timeline ☒ Hierarchial Timeline

Timeline Options

● Sort by agent ○ Sort by time

Activities
Time (m)
0
25
50
75
100
125
150
175
200
225
250
275
extract-ddcu2993: minute 192 to minute 212
🟥 adco 🟦 phalcon 🟩 odin 🟨 bob 🟪 sally 🟦 thor 🟥 crew

Available Actions ☒ Procedure

Property	Value
sarj-cover-remove	
sarj-lube-setup	
vent-p6	
vent-tool-clean-up	
vent-tool-setup	
p3-p4-nh3-jumper-stow	
p3-p4-nh3-jumper-rer…	
open-final-qds	
p6-radiator-fill	
retrieve-item	
retrieve-item2	
go-install-item	
install-item-in-place	
ddcu-r&r-prep	
ddcu-change-out	
lock-sarj-with-shutdown	
recover-sarj-to-mode	
s-band-swap	
deactivate-rga	
reconfig-gps-power	
shutdown-cmg	
activate-ceta-lights	
configure-sarj-monitor	
configure-sarj-comman…	
deactivate-ext-mdm	

Selected Actions ☒ Plan Images

Planning time: 390 minutes

Name	What	Who	Where
retrieve-item_a	ceta-light1	sally	
install-item_a	power-cable1	?ev	
install-item_a	fqd-jumper1	?ev	
site-prepped-for-r&r	ddcus01a	?ev	
replaced	ddcus01a	sally	
deactivate-rga_a	ddcus01a	?fc	
reconfig-gps-power_a	ddcus01a	?fc	
shutdown-cmg_a	ddcus01a	?fc	
configure-sarj_a	sarj-starboard	?fc	
configure-sarj_a	sarj-port	?fc	
transition-mdm_a	str-mdm	?fc	
transition-p1-mdm_a	p1-mdm2	?fc	
transition-p3-mdm_a	p3-mdm1	?fc	
shutdown-etcs-loop_a	ddcus01a	?fc	
deactivate-ddcu_a	ddcus01a	?fc	
powerdown-ddcu_a	ddcus01a	?fc	

Plan achieved.

Details

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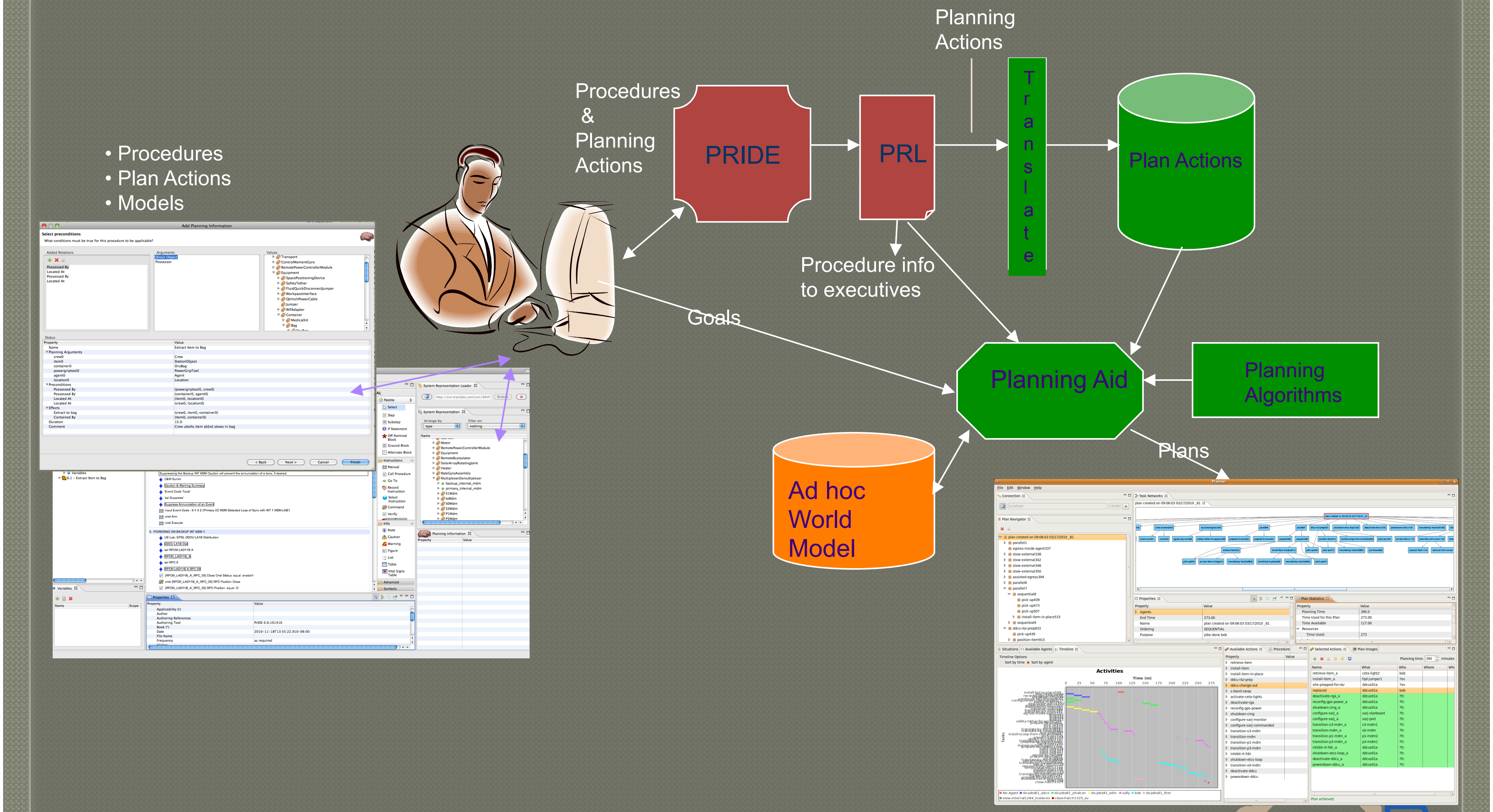

Procedures & Planning Actions

PRIDE

PRL

Planning Actions

Translate

Plan Actions

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Ad hoc World Model

Plans

Ontological Development Environment

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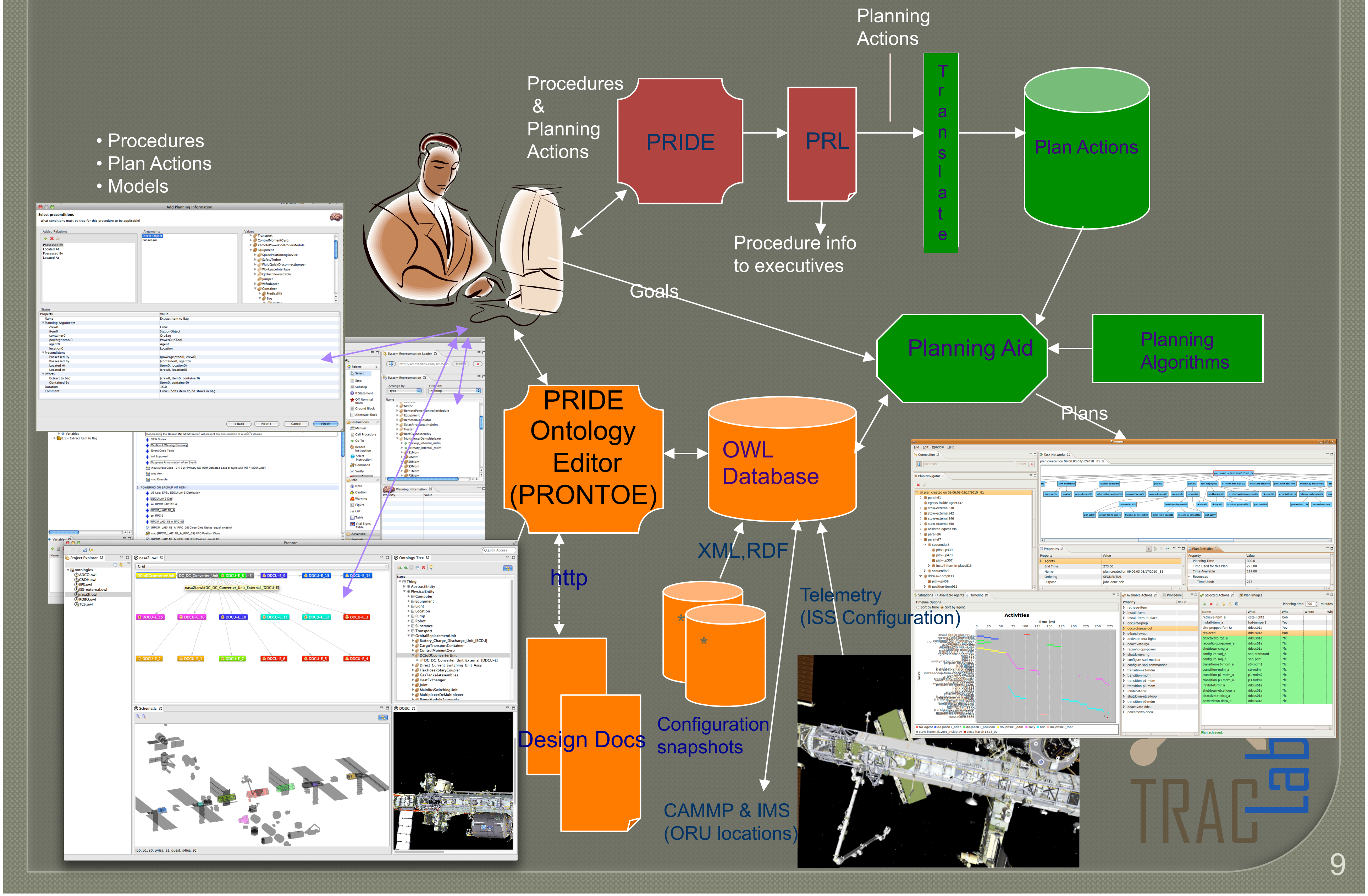


Some PRONTOE Capabilities

- User doesn’t need to know about ontologies
- Add/delete/modify data to support procedure authoring
- Navigate graphically through the ontological hierarchy
- Invoke ontological reasoners to speed relation entries
- Author and save what-if snapshots to use for planning future activities
- Integrate with PRIDE Planning Wizard
  - Classes, instances and relations
  - Axioms for bookkeeping and constraint management
- Output to OWL files
  - To be read and updated by planning systems
  - To be read and updated by procedure execution systems

Types of Ontological Information

- Classes, subclasses and relations among them
  - truss-segment, ORU*-bag, ceta-light
  - can-hold (medium-ORU-bag, ceta-light)
- Class instances
  - LAB-ceta-light1, S1
  - located (LAB-ceta-light1) = S1
- Directives
  - Preconditions and effects, e.g., crew must possess a PGT before unbolting a CETA light
  - Axioms for bookkeeping and physics, e.g., if a container is located at A, so are its contents
  - Constraints (includes flight rules), e.g., if a CETA-light heater is not on then its lamp must be on
- Data - facts that represent a specific configuration of all the instances, e.g., switch settings, modes, locations

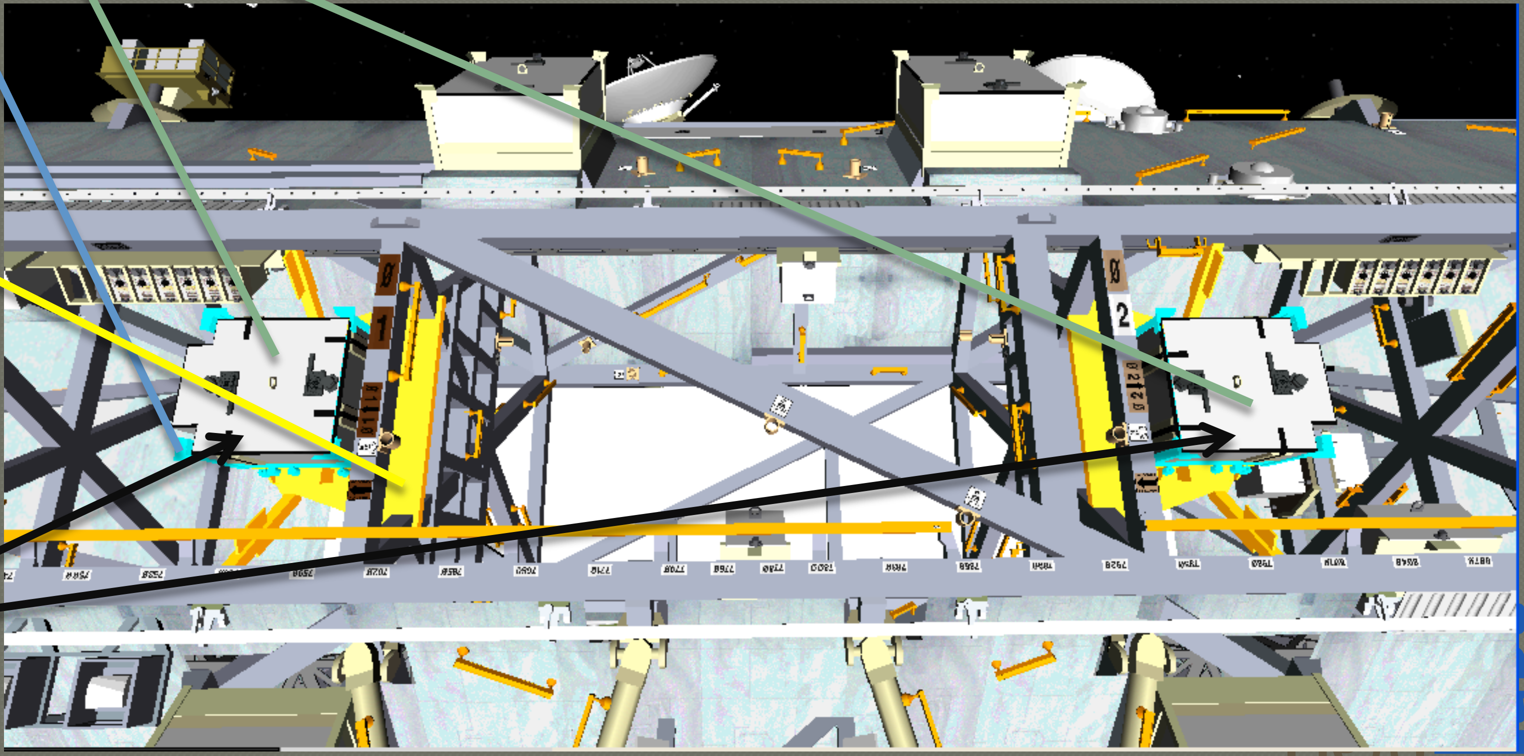
*orbital replacement unit

Divisions in the Ontology

- The *base*
  - "Floor" of the ontology = classes and relations based on modeling choices, e.g.,
  - Includes axioms
  - Not editable by users
  - We have an "all domains" base & an "ISS-base"
- The *kernel extensions*
  - Per flight discipline, e.g., PHALCON, EVA
  - A starting set of classes and instances of the ISS to be edited and expanded by users
- The ontological *data*
  - Collection of facts that represent a specific configuration of all the instances
  - Can be updated both manually and electronically

DDCUs for Big 12

Note: DDCU S01A is also the name of the location. E.g., if that DDCU is replaced, the new one is “called” DDCU S01A.



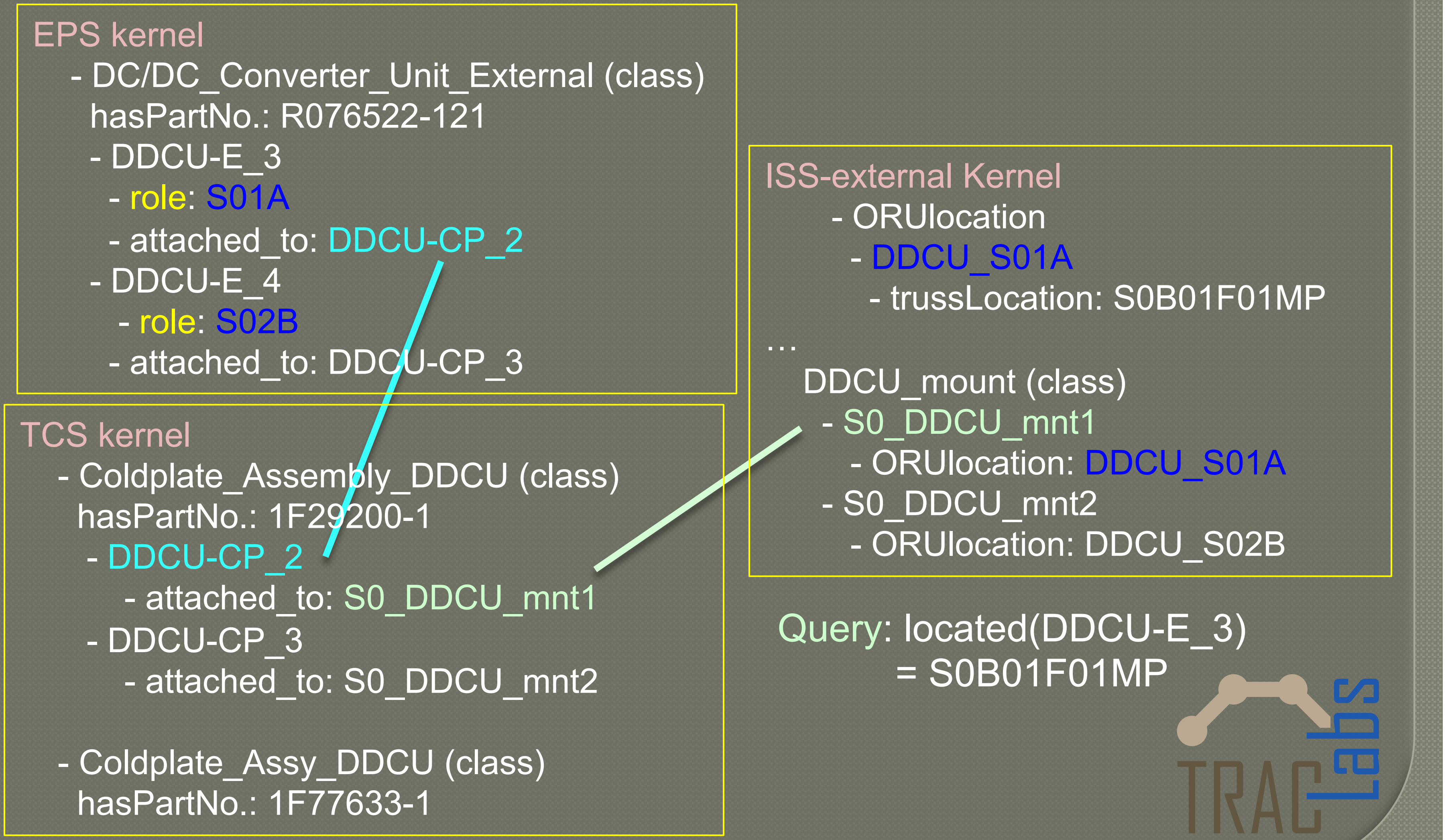
DDCU S01A
DDCU S02B

Attached to DDCU Cold Plates

Cold plates are attached to DDCU mounts

Mounts are located at truss locations
S0B01F01MP
S0B02F01MS

DDCU – location modeling



EPS kernel

- DC/DC_Converter_Unit_External (class)
  hasPartNo.: R076522-121
  - DDCU-E_3
    - role: S01A
    - attached_to: DDCU-CP_2
  - DDCU-E_4
    - role: S02B
    - attached_to: DDCU-CP_3

TCS kernel

- Coldplate_Assembly_DDCU (class)
  hasPartNo.: 1F29200-1
  - DDCU-CP_2
    - attached_to: S0_DDCU_mnt1
  - DDCU-CP_3
    - attached_to: S0_DDCU_mnt2
- Coldplate_Assy_DDCU (class)
  hasPartNo.: 1F77633-1

ISS-external Kernel

- ORUlocation
  - DDCU_S01A
    - trussLocation: S0B01F01MP

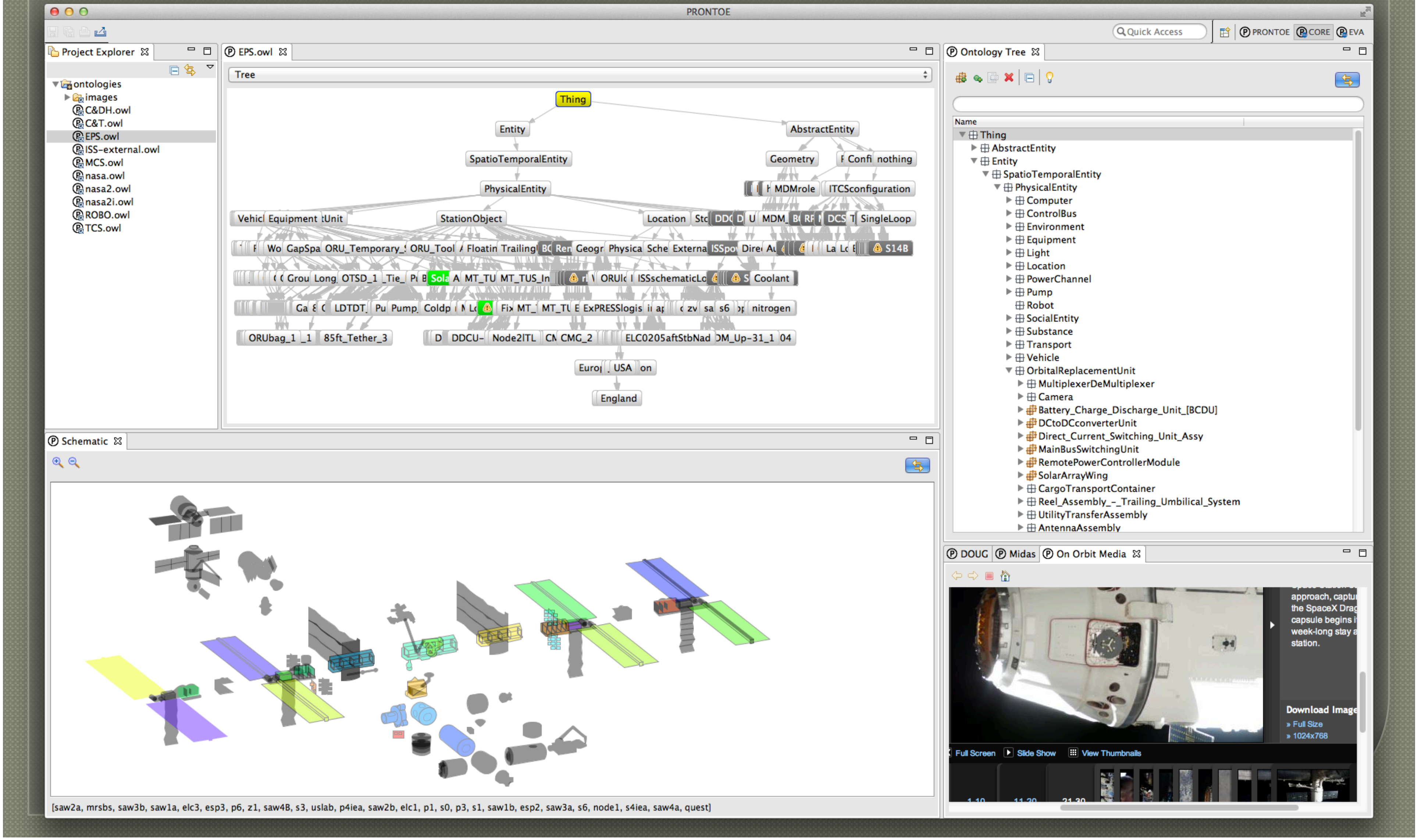
…

DDCU_mount (class)

- S0_DDCU_mnt1
  - ORUlocation: DDCU_S01A
- S0_DDCU_mnt2
  - ORUlocation: DDCU_S02B

Query: located(DDCU-E_3)
= S0B01F01MP

PRIDE Ontology Editor (PRONTOE)

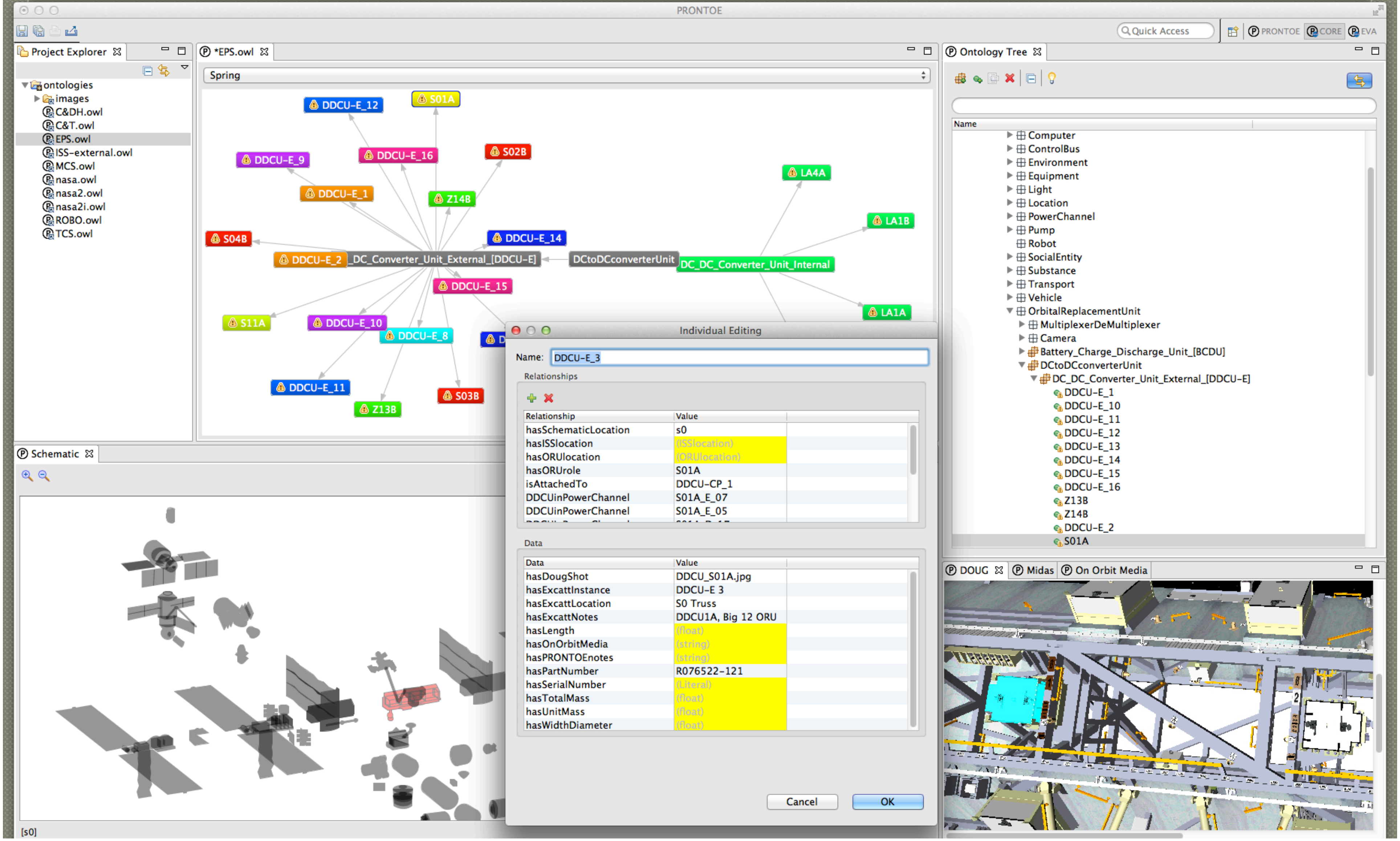


- ontologies
  - images
  - C&DH.owl
  - C&T.owl
  - EPS.owl
  - ISS-external.owl
  - MCS.owl
  - nasa.owl
  - nasa2.owl
  - nasa2i.owl
  - ROBO.owl
  - TCS.owl

- Thing
  - AbstractEntity
  - Entity
    - SpatioTemporalEntity
      - PhysicalEntity
        - Computer
        - ControlBus
        - Environment
        - Equipment
        - Light
        - Location
        - PowerChannel
        - Pump
        - Robot
        - SocialEntity
        - Substance
        - Transport
        - Vehicle
        - OrbitalReplacementUnit
          - MultiplexerDeMultiplexer
          - Camera
          - Battery_Charge_Discharge_Unit_[BCDU]
          - DCtoDCconverterUnit
          - Direct_Current_Switching_Unit_Assy
          - MainBusSwitchingUnit
          - RemotePowerControllerModule
          - SolarArrayWing
          - CargoTransportContainer
          - Reel_Assembly_-_Trailing_Umbilical_System
          - UtilityTransferAssembly
          - AntennaAssembly

[saw2a, mrsbs, saw3b, saw1a, elc3, esp3, p6, z1, saw4B, s3, uslab, p4iea, saw2b, elc1, p1, s0, p3, s1, saw1b, esp2, saw3a, s6, node1, s4iea, saw4a, quest]

PRIDE Ontology Editor (PRONTOE)



Name: DDCU-E_3

Relationships

Relationship	Value
hasSchematicLocation	s0
hasISSlocation	(ISSlocation)
hasORUlocation	(ORUlocation)
hasORUrole	S01A
isAttachedTo	DDCU-CP_1
DDCUinPowerChannel	S01A_E_07
DDCUinPowerChannel	S01A_E_05

Data

Data	Value
hasDougShot	DDCU_S01A.jpg
hasExcattInstance	DDCU-E 3
hasExcattLocation	S0 Truss
hasExcattNotes	DDCU1A, Big 12 ORU
hasLength	(float)
hasOnOrbitMedia	(string)
hasPRONTOEnotes	(string)
hasPartNumber	R076522-121
hasSerialNumber	(Literal)
hasTotalMass	(float)
hasUnitMass	(float)
hasWidthDiameter	(float)

OWL->PDDL*

- Direct subclasses => types/subtypes
- Class assertions => instances
- Object properties => predicate definitions
- Object property assertions => predicate assertions

*PDDL-e = PDDL 2.1 + axioms + hierarchical actions

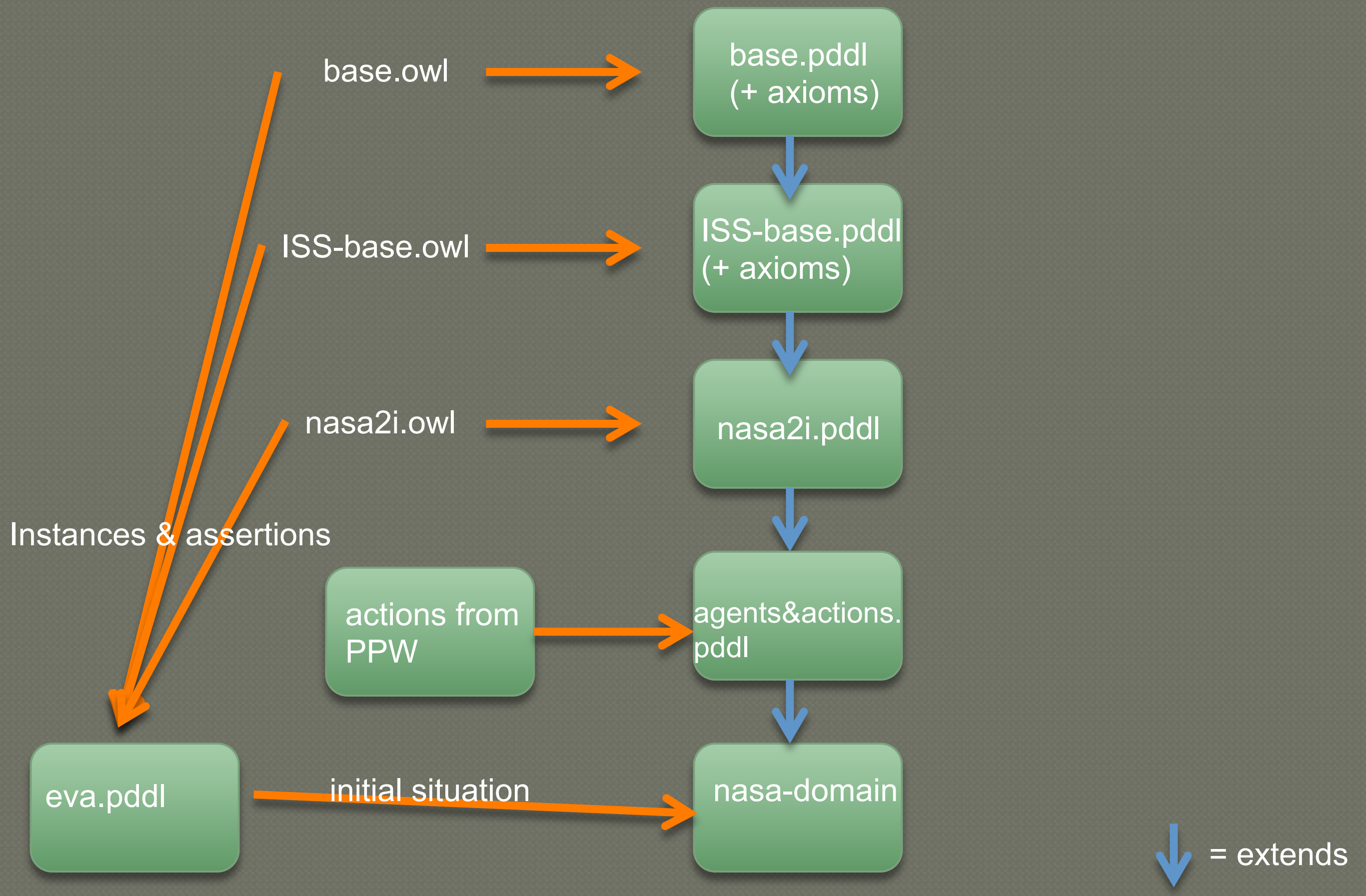
Axioms – OWL

```
Container(?x), PhysicalEntity(?y),
ISSlocation(?z), contains(?x, ?y),
hasISSlocation(?x, ?z)
->
hasISSlocation(?y, ?z)
```

```
(:axiom
  :vars (?x - container
         ?y - physical-entity
         ?z - iss-location)
  :context (and (contains ?x ?y)
                (has-iss-location ?x ?z))
  :implies (has-iss-location ?y ?z)
)
```

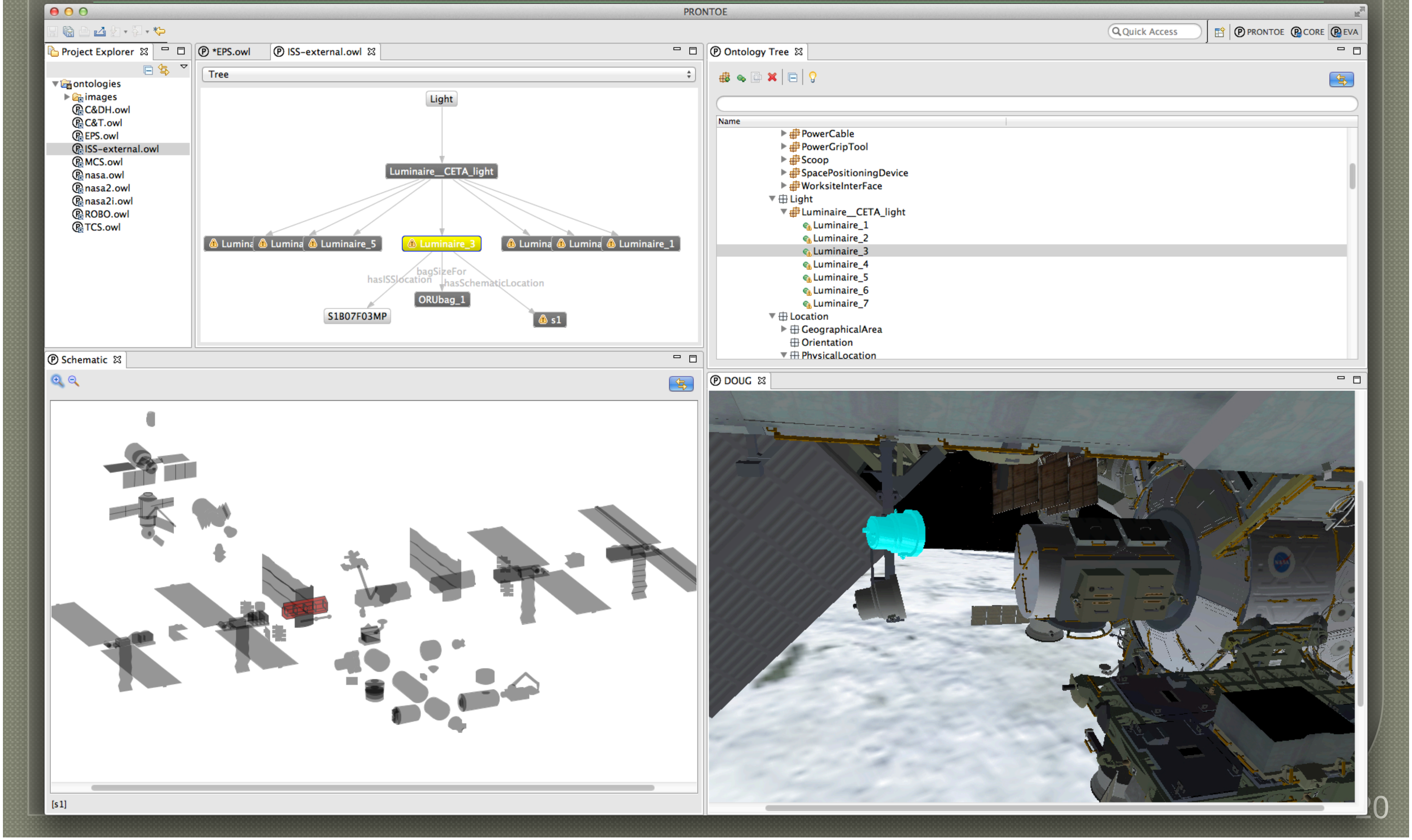
```
<DLSafeRule>
  <Body>
    <ClassAtom>
      <Class abbreviatedIRI="base:Container"/>
      <Variable IRI="urn:swrl#x"/>
    </ClassAtom>
    <ClassAtom>
      <Class abbreviatedIRI="base:PhysicalEntity"/>
      <Variable IRI="urn:swrl#y"/>
    </ClassAtom>
    <ClassAtom>
      <Class abbreviatedIRI="ISS-base:ISSlocation"/>
      <Variable IRI="urn:swrl#z"/>
    </ClassAtom>
    <ObjectPropertyAtom>
      <ObjectProperty abbreviatedIRI="base:contains"/>
      <Variable IRI="urn:swrl#x"/>
      <Variable IRI="urn:swrl#y"/>
    </ObjectPropertyAtom>
    <ObjectPropertyAtom>
      <ObjectProperty abbreviatedIRI="ISS-base:hasISSlocation"/>
      <Variable IRI="urn:swrl#x"/>
      <Variable IRI="urn:swrl#z"/>
    </ObjectPropertyAtom>
  </Body>
  <Head>
    <ObjectPropertyAtom>
      <ObjectProperty abbreviatedIRI="ISS-base:hasISSlocation"/>
      <Variable IRI="urn:swrl#y"/>
      <Variable IRI="urn:swrl#z"/>
    </ObjectPropertyAtom>
  </Head>
</DLSafeRule>
```

PDDL Hierarchy



TRAC Labs

CETA Light 3


PRONTOE
Quick Access
PRONTOE
CORE
EVA
Project Explorer
ontologies
images
C&DH.owl
C&T.owl
EPS.owl
ISS-external.owl
MCS.owl
nasa.owl
nasa2.owl
nasa2i.owl
ROBO.owl
TCS.owl
*EPS.owl
ISS-external.owl
Tree
Light
Luminaire__CETA_light
Lumina
Lumina
Luminaire_5
Luminaire_3
Lumina
Lumina
Luminaire_1
bagSizeFor
hasISSlocation
hasSchematicLocation
ORUbag_1
S1B07F03MP
s1
Ontology Tree
Name
PowerCable
PowerGripTool
Scoop
SpacePositioningDevice
WorksiteInterFace
Light
Luminaire__CETA_light
Luminaire_1
Luminaire_2
Luminaire_3
Luminaire_4
Luminaire_5
Luminaire_6
Luminaire_7
Location
GeographicalArea
Orientation
PhysicalLocation
Schematic
DOUG
[s1]

actions & a problem

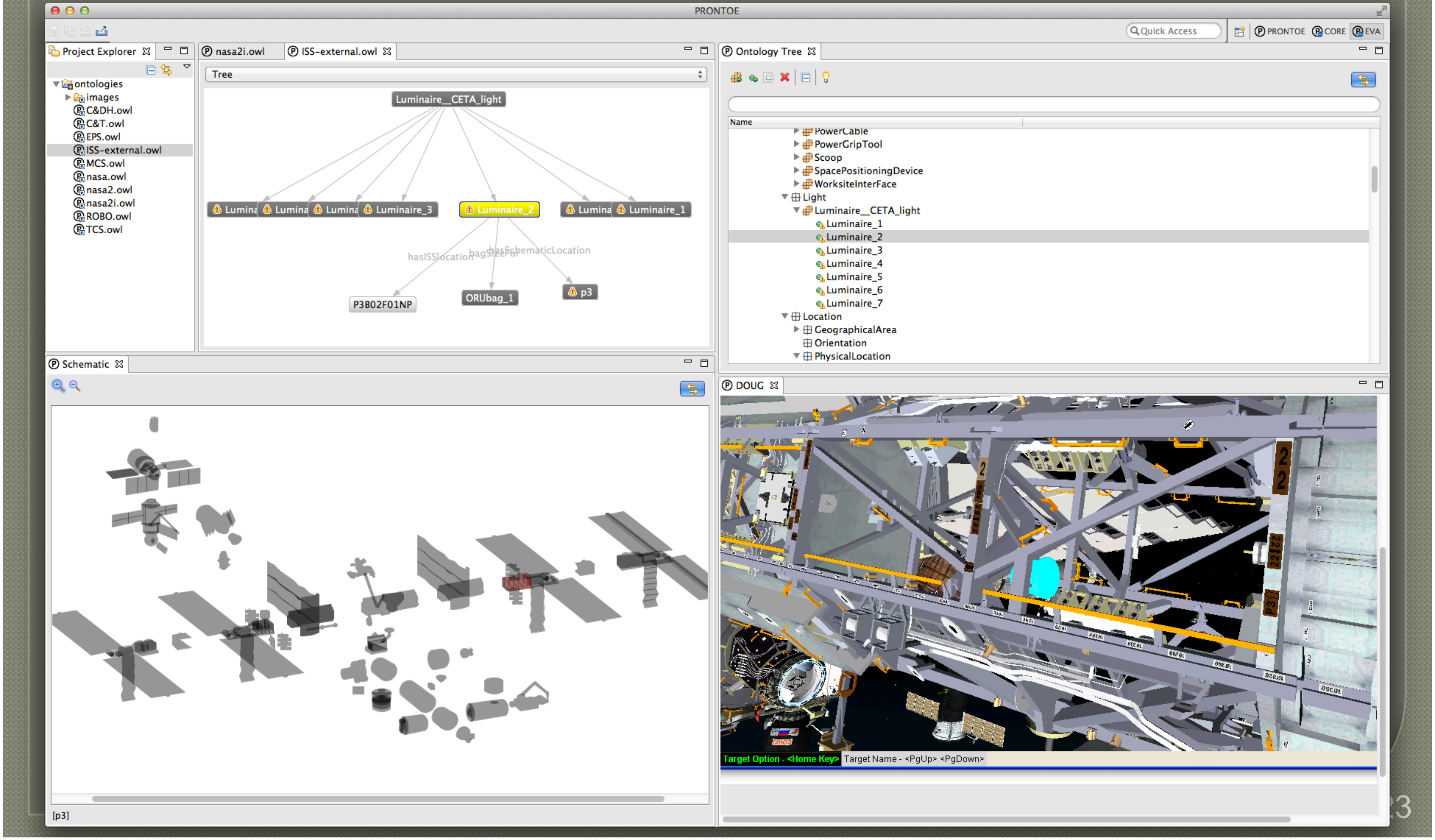
```
(define (durative-action Translate-by-handrail)
   :parameters (?ev - crew
                  ?end-loc - iss-location)
   :vars (?start-loc - iss-location)
   :condition (at start (has-iss-location ?ev ?start-loc))
   :effect (at end (has-iss-location ?ev ?end-loc))
   :duration time-from-path
   :comment "?ev travels by handrail from ?start-loc to ?end-loc")

 (define (durative-action Extract-item-to-bag)
   :parameters (?ev - crew
                  ?item - (or luminaire__ceta_light
                             control-panel-assembly)
                 ?container - oru-bag)
   :vars (?pgt - pgt-with-turn-setting
          ?l - (has-iss-location ?item))
   :duration 12.0
   :condition (and (at start (has-iss-location ?ev ?l))
                   (at start (possesses ?ev ?container))
                   (at start (= (possessed_by ?pgt) ?ev))
                   (at start (bag-size-for ?item ?container)))
   :effect (and (at end (extracted-item-to ?ev ?item ?container))
                 (at end (contains ?container ?item))
                               )
   :comment "crew removes ?item at ?l and stows in bag."
   )
```

```
(define (durative-action Retrieve-item)
   :parameters (?ev - crew
                  ?item - (or luminaire__ceta_light
                               control-panel-assembly
                               power-cable
                               space-positioning-device))
   :vars (?container - (or oru-bag fish-stringer)
          ?loc - (has-iss-location ?item))
   :expansion (sequential
                (possesses ?ev ?container)
                (has-iss-location ?ev ?loc)
                (extracted-item-to ?ev ?item ?container)
               )
   :effect (at end (retrieve-item_a ?ev ?item))
   :comment "?ev picks up ?container, travels to ?item's loc,
     unmounts and stores ?item in ?container and returns.")

(define (problem bob-get-light)
   (:domain nasa-domain)
  (:situation phalcon-eva)
  (:deadline 100.0)
  (:init (has-iss-location bob airlock)
         (possesses bob oru-bag_1)
         (possesses bob pgt_1))
  (:goal (retrieve-item_a bob LUMINAIRE_3))
  )
```

plan achieved

```
purpose-established RETRIEVE-ITEM0: RETRIEVE-ITEM_A(BOB,LUMINAIRE_3)

Thus ends the plan-generation phase of BOB-GET-LIGHT ...

-------- plan: RETRIEVE-ITEM0 --------
RETRIEVE-ITEM0: RETRIEVE-ITEM_A(BOB,LUMINAIRE_3)
  sequential
    BOB-GET-LIGHT_IS: POSSESSES(BOB,ORU-BAG_1)
    TRANSLATE-BY-HANDRAIL13: HAS-ISS-LOCATION(BOB,S1B07F03MP)
    EXTRACT-ITEM-TO-BAG56: EXTRACTED-ITEM-TO(BOB,LUMINAIRE_3,ORU-BAG_1)

 probability-of-success = 0.902
 duration = 27.00

 +nodes-examined+ = 4
 +constraints-tested+ = 0
 +axioms-applied+ = 3

  0.05 CPU seconds [0.012 CPU sec/node]

RETRIEVE-ITEM0
```

CETA Light 2


PRONTOE
Quick Access
PRONTOE
CORE
EVA
Project Explorer
ontologies
images
C&DH.owl
C&T.owl
EPS.owl
ISS-external.owl
MCS.owl
nasa.owl
nasa2.owl
nasa2i.owl
ROBO.owl
TCS.owl
nasa2i.owl
ISS-external.owl
Tree
Luminaire__CETA_light
Lumina
Lumina
Lumina
Luminaire_3
Luminaire_2
Lumina
Luminaire_1
hasISSlocation
bagSizeFor
hasSchematicLocation
P3B02F01NP
ORUbag_1
p3
Ontology Tree
Name
PowerCable
PowerGripTool
Scoop
SpacePositioningDevice
WorksiteInterFace
Light
Luminaire__CETA_light
Luminaire_1
Luminaire_2
Luminaire_3
Luminaire_4
Luminaire_5
Luminaire_6
Luminaire_7
Location
GeographicalArea
Orientation
PhysicalLocation
Schematic
[p3]
DOUG
Target Option - <Home Key>
Target Name - <PgUp> <PgDown>

more actions & a 2nd problem

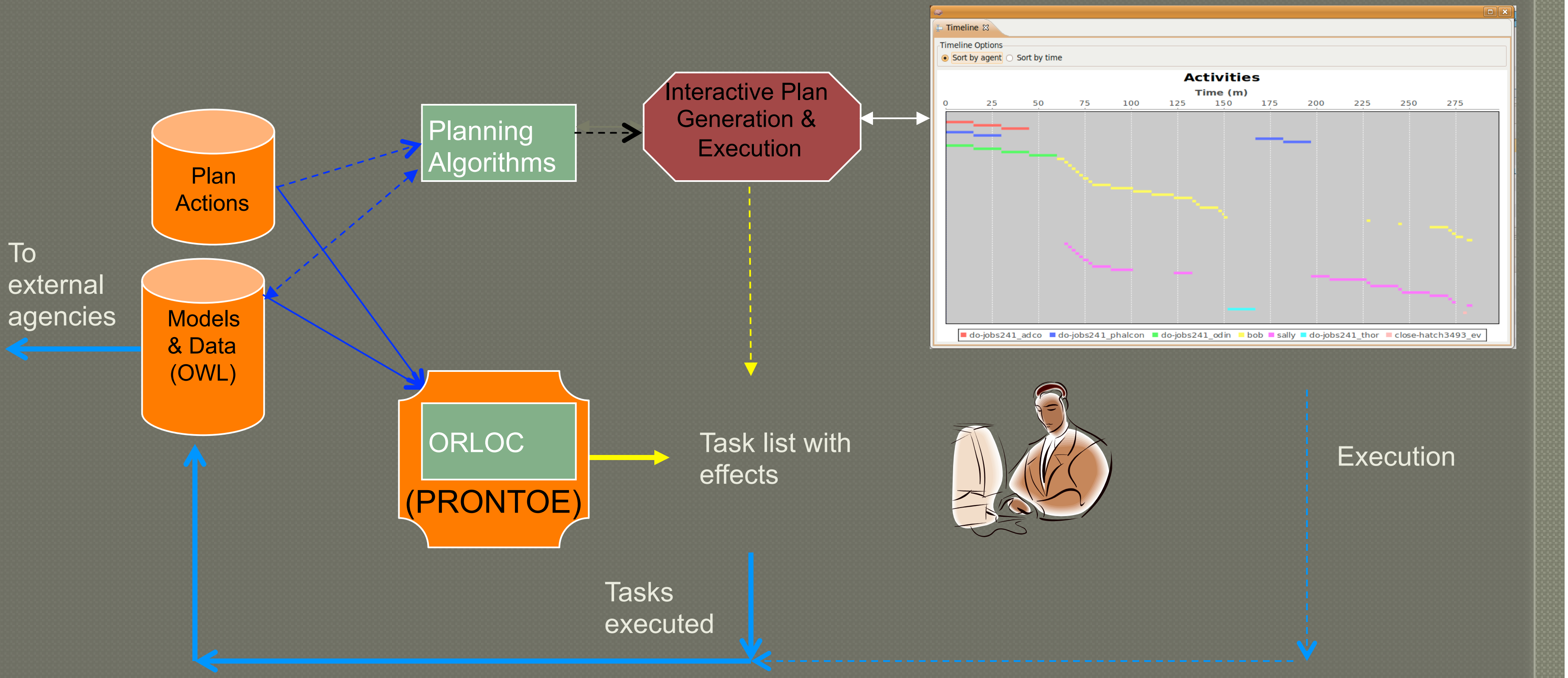
```
(define (durative-action install-tether&swap)
   :parameters (?ev - crew
                    ?st1 ?st2 - safety-tether)
   :vars (?l - (has-iss-location ?ev)
          ?stp - safety-tether-pack)
   :condition (and (at start (not (= ?st1 ?st2)))
                   (at start (tethered_to ?st1 ?ev))
                   (at start (contains ?stp ?st2))
                   (at start (has-iss-location ?stp ?l))
                  )
   :effect (and (at end (not (contains ?stp ?st2)))
                (at end (tethered_to ?st2 ?ev))
                (at end (has-iss-location ?st2 ?l))
                (at end (tether-swapped ?ev ?st1)))
   :duration 5
   :comment "?ev installs a second tether and then swaps
             his current tether for the new one.")
```

```
(define (durative-action Translate-by-hr&swap)
   :parameters (?ev - crew
                    ?end-loc - location)
   :vars (?start-loc - (has-iss-location ?ev)
          ?mloc - (intermediate-loc-for ?start-loc ?end-loc)
          ?st - safety-tether)
   :condition (and
                  (at start (too-far ?start-loc ?end-loc))
                  (at start (not (= ?start-loc ?end-loc)))
                  (at start (tethered_to ?st ?ev))
                  )
   :expansion (sequential
                  (has-iss-location ?ev ?mloc)
                  (tether-swapped ?ev ?st)
                  (has-iss-location ?ev ?end-loc)
                  )
   :effect (at end (has-iss-location ?ev ?end-loc))
   :duration time-from-path
   :comment "?ev travels by handrail to ?end-loc via ?mloc")

(define (problem bob-get-light2)
   (:domain nasa-domain)
   (:situation phalcon-eva)
   (:deadline 100.0)
   (:init          (has-iss-location bob airlock)
                   (possesses bob oru-bag_1)
                   (possesses bob pgt_1)
                   (tethered_to 85-ft_tether_3 bob)
                   (possesses bob stp_1))
  (:goal (retrieve-item_a bob LUMINAIRE_2))
  )
```

2nd plan achieved

```
purpose-established RETRIEVE-ITEM0: RETRIEVE-ITEM_A(BOB,LUMINAIRE_2)

Thus ends the plan-generation phase of BOB-GET-LIGHT2 ...

-------- plan: RETRIEVE-ITEM0 --------
RETRIEVE-ITEM0: RETRIEVE-ITEM_A(BOB,LUMINAIRE_2)
  sequential
    BOB-GET-LIGHT2_IS: POSSESSES(BOB,ORU-BAG_1)
    TRANSLATE-BY-HR&SWAP3: HAS-ISS-LOCATION(BOB,P3B02F01NP)
      sequential
        TRANSLATE-BY-HANDRAIL78: HAS-ISS-LOCATION(BOB,P1B10F01MM)
        INSTALL-TETHER&SWAP135: TETHER-SWAPPED(BOB,85-FT_TETHER_3)
        TRANSLATE-BY-HANDRAIL182: HAS-ISS-LOCATION(BOB,P3B02F01NP)
    EXTRACT-ITEM-TO-BAG213: EXTRACTED-ITEM-TO(BOB,LUMINAIRE_2,ORU-BAG_1)

 probability-of-success = 0.815
 duration = 32.00

 +nodes-examined+ = 8
 +constraints-tested+ = 0
 +axioms-applied+ = 20

  0.19 CPU seconds [0.024 CPU sec/node]

RETRIEVE-ITEM0
```

Tracking ORU Locations Changes (ORLOC Tool)



Plan Actions

Models & Data (OWL)

To external agencies

Planning Algorithms

Interactive Plan Generation & Execution

Timeline

Timeline Options

● Sort by agent ○ Sort by time

ORLOC (PRONTOE)

Task list with effects

Execution

Tasks executed

Future Work

- Finalize PRONTOE version 1.0 based on flight controller feedback
- Begin work on ORLOC capabilities
  - Task lists imply location and setting changes
  - HTTP interface to DOUG for 3D visualization
- Develop axiom translator for PPW
  - Direct parse for axiomatic languages (e.g., PDDL-e)
  - Pre-processing* of axioms for non-axiomatic languages (e.g., ANML, AML)
- Recreate all plans for DDCU R&R scenario
- Develop streaming data updates

*e.g., Davidson & Garagnani (Plan-SIG02)

Discussion