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MINISTÈRE DE LA DÉFENSE

Goal driven planning and adaptivity for AUVs

CAR06

DGA

DÉLÉGATION GÉNÉRALE POUR L'ARMEMENT
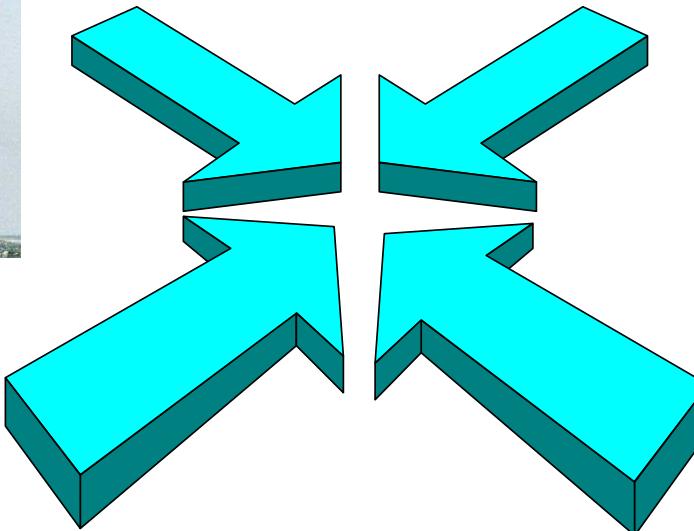
GESMA : Location

GESMA : Skills & Missions

Mine warfare
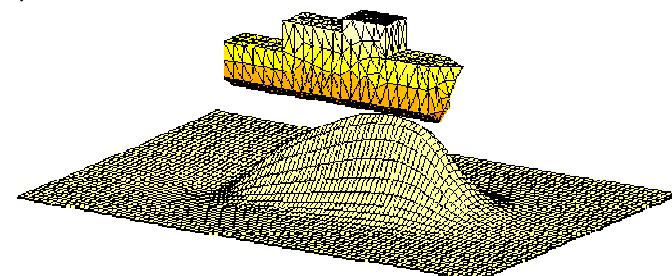
Robotics

Underwater Warfare Environment

Platform susceptibility

GESMA

GESMA

DGA expert

in marine robotics

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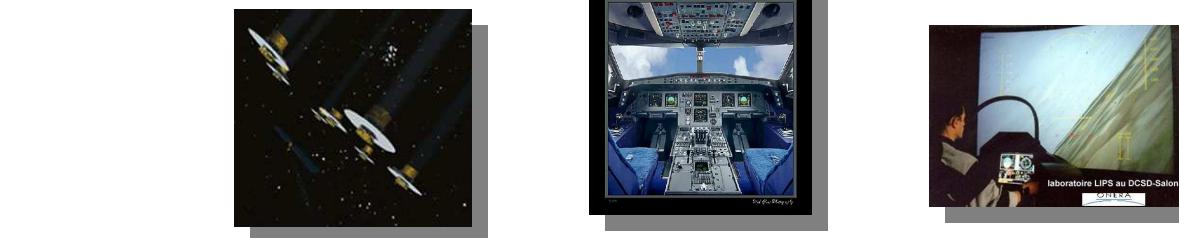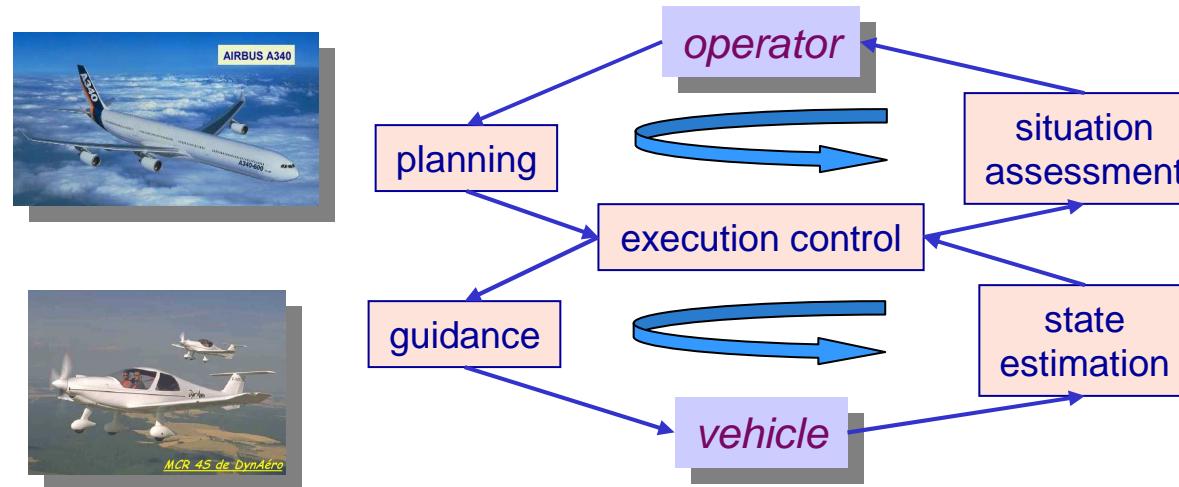
ONERA : French Aeronautics and Space Research Center

**DCSD Lab:** Systems Control and Flight Dynamics Department

ONERA

Human Factors

*operator*

planning

situation assessment

Decision

execution control

guidance

state estimation

Control

vehicle
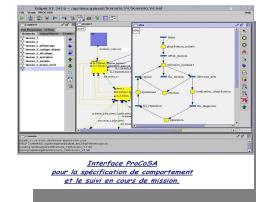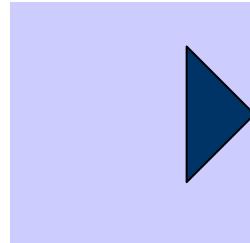
Flight mechanics & Identification

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PROLEXIA

- Small company
- Simulation
- Mission planning tools

Gesma studies on planning tools

- Assess requirements for mission planning tools for different levels of autonomy

- Assess adaptivity for Mine Warfare and REA missions

DGA

Levels of autonomy

Level 4 : Fully autonomous mission

Level 3 : Goal driven planning & Operator supervision

Level 2 : Geographic trajectory planning (Wpts)

Level 1: Ordered set of elementary controls

Level 0 : teleoperation

Military requirements

•Low bandwidth communication
•Discrete or Unsupervised AUV mission
•Unknown or hostile environment

Autonomy

Adaptivity

goal driven planning

Examples of goals

- Find a wreck (or plane black boxes)

- Survey a zone for mines detection, classification and identification

- Find a free path suitable for amphibious assault

Examples of adaptivity

- If the current is strong and not in the main survey direction, change the survey direction

- If something is detected, try to classify by multi-aspect sonar acquisition

- If something is classify, try to identify by going over at low altitude

- If enter a posidony field, change mapping strategy

- If sand ripples prevent from good detection, plan another survey perpendicular to main sand ripples direction

Mission planning

- Data quality insurance
  - Exhaustivity (coverage, overlap, redundancy)
  - Accuracy (altitude related to sensor definition, environment)
  - Confidence (computer aided decision, performance criteria, navigation errors)

- AUV security insurance
  - Bathymetry
  - Forbidden area
  - Security immersion in traffic zone
  - Strong currents

- Mission optimization
  - Mainly for energy consumption
  - Time/tide/currents
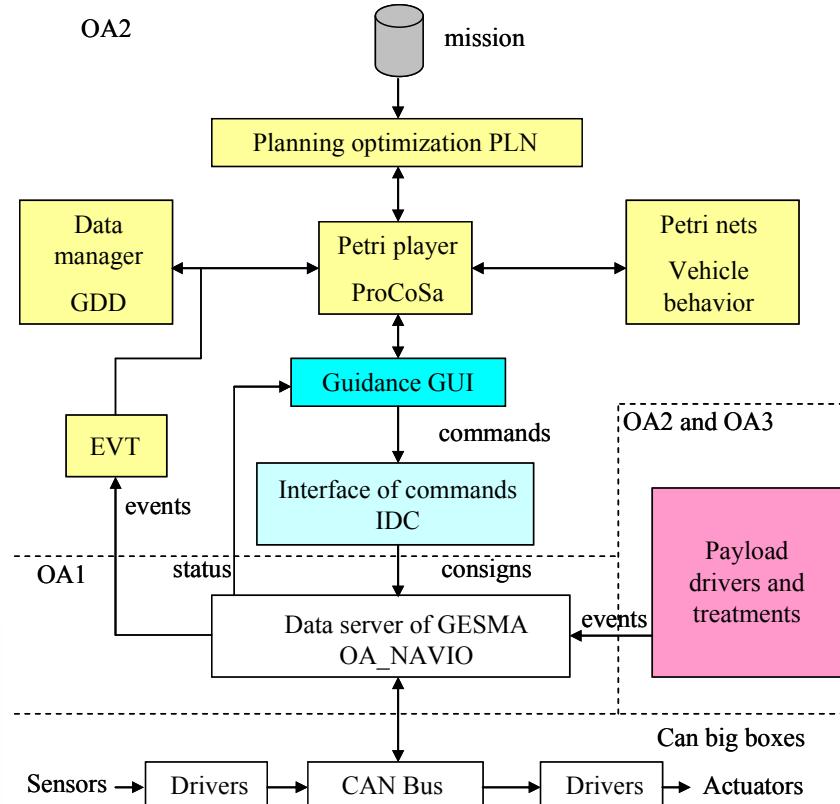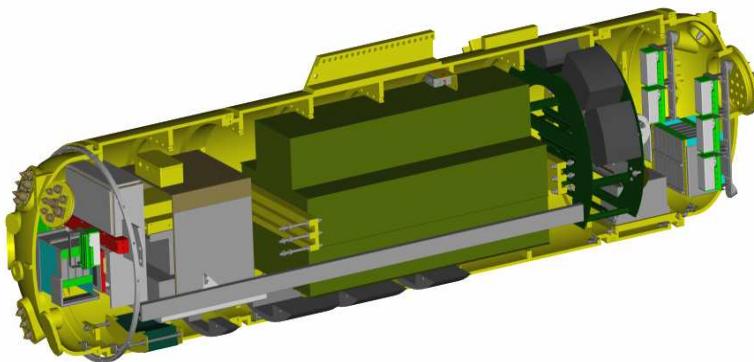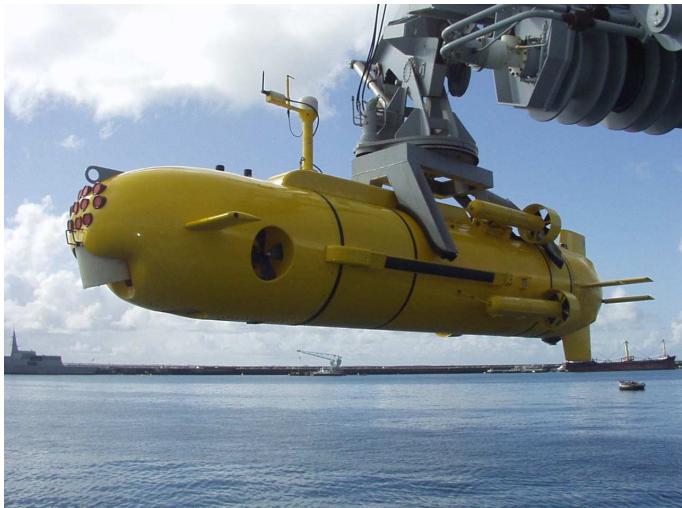
What you need is:

- A nice AUV
  - Redermor platform

- User friendly Operator MMI
  - Preparation / Supervision

- Environmental database
  - SHOM METOC guide / C-Map

- Automatic planning algorithm
  - Dijkstra and Little algorithms (shortest path, lowest cost)

- Onboard supervision system
  - Petri nets

- Events generation by sensors measurements and computer aided treatments on sonars

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The nice AUV : Redermor

OA2 · mission

```
                 [mission]
                    |
                    v
        Planning optimization PLN
                    |
                    v
Data manager  <-->  Petri player  <-->  Petri nets
GDD                 ProCoSa              Vehicle behavior
                        |
                        v
                  Guidance GUI
                        |
              commands  |          OA2 and OA3
   EVT                  v
              Interface of commands
                        IDC
    events                              Payload drivers
                                        and treatments
OA1   status      consigns    events
              Data server of GESMA
              OA_NAVIO
                                        Can big boxes
Sensors -> Drivers -> CAN Bus -> Drivers -> Actuators
```

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Mission planning MMI

- level 1 : text editor Or NIVAS/IOVAS

- level 2 : FLEET MANAGER

- level 3 and 4 : NIVAS/IOVAS
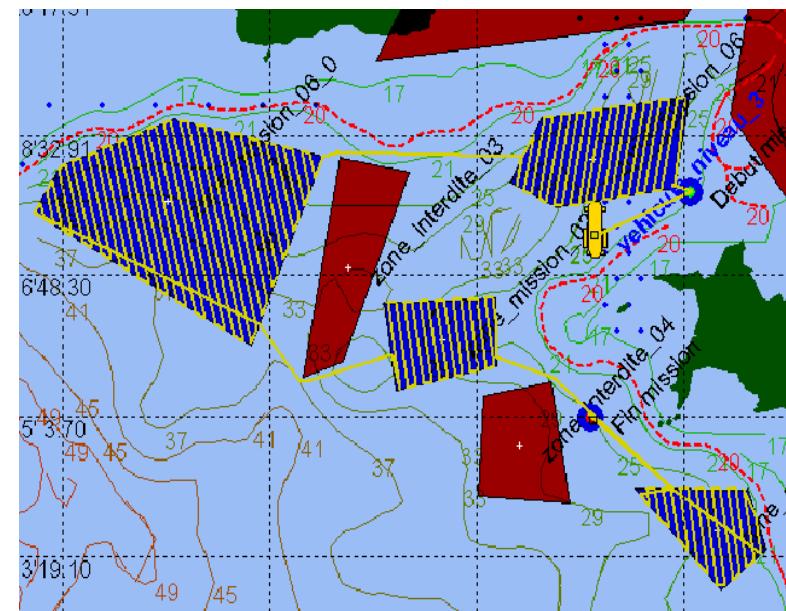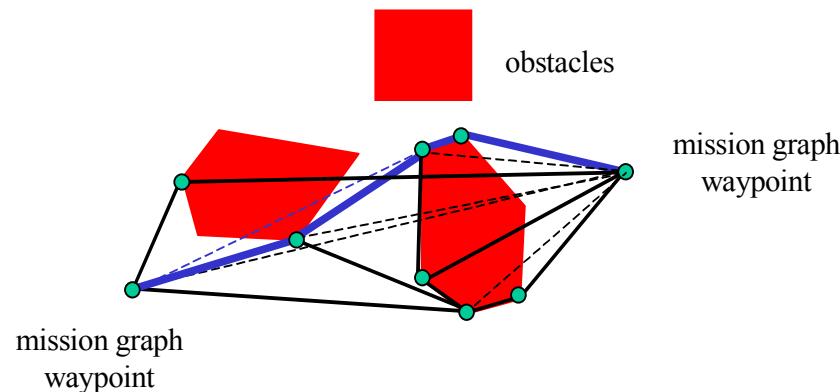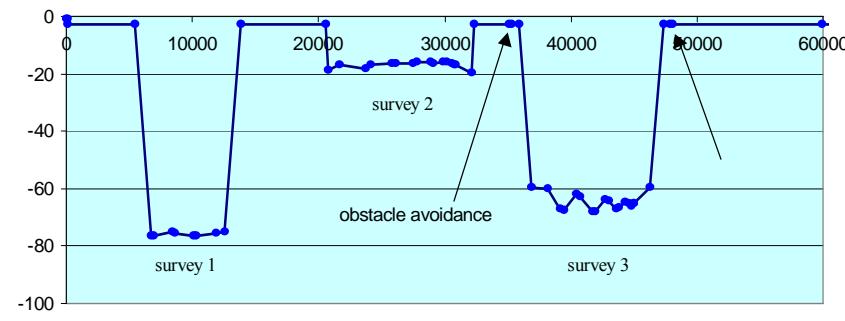
Environmental database

Planning algorithms

obstacles

mission graph waypoint

mission graph waypoint
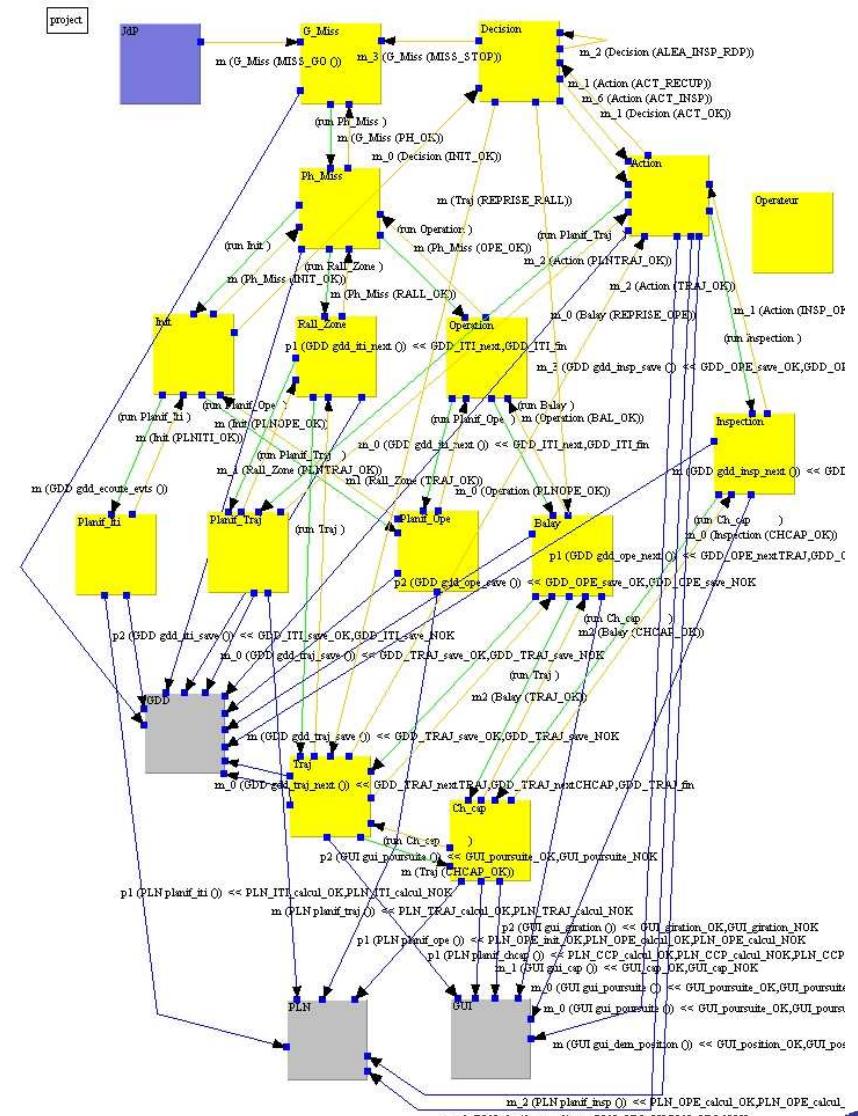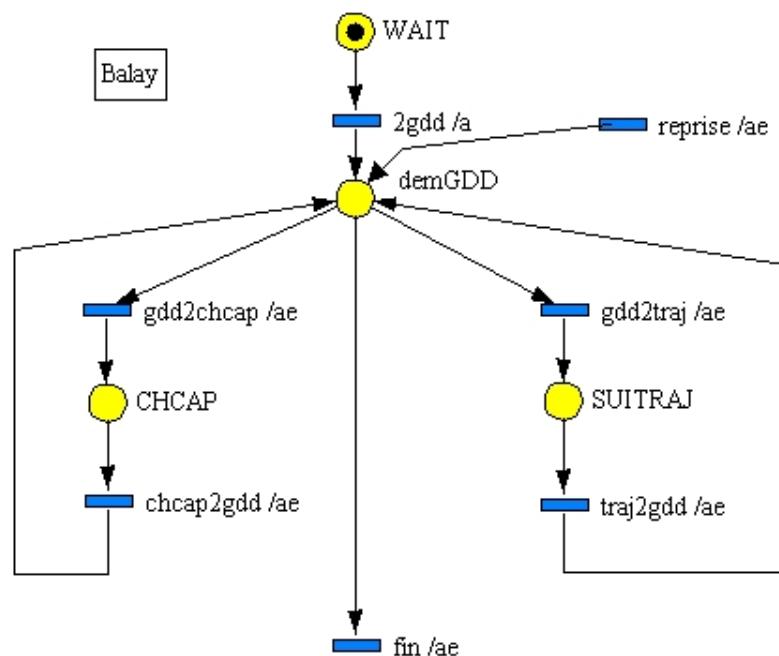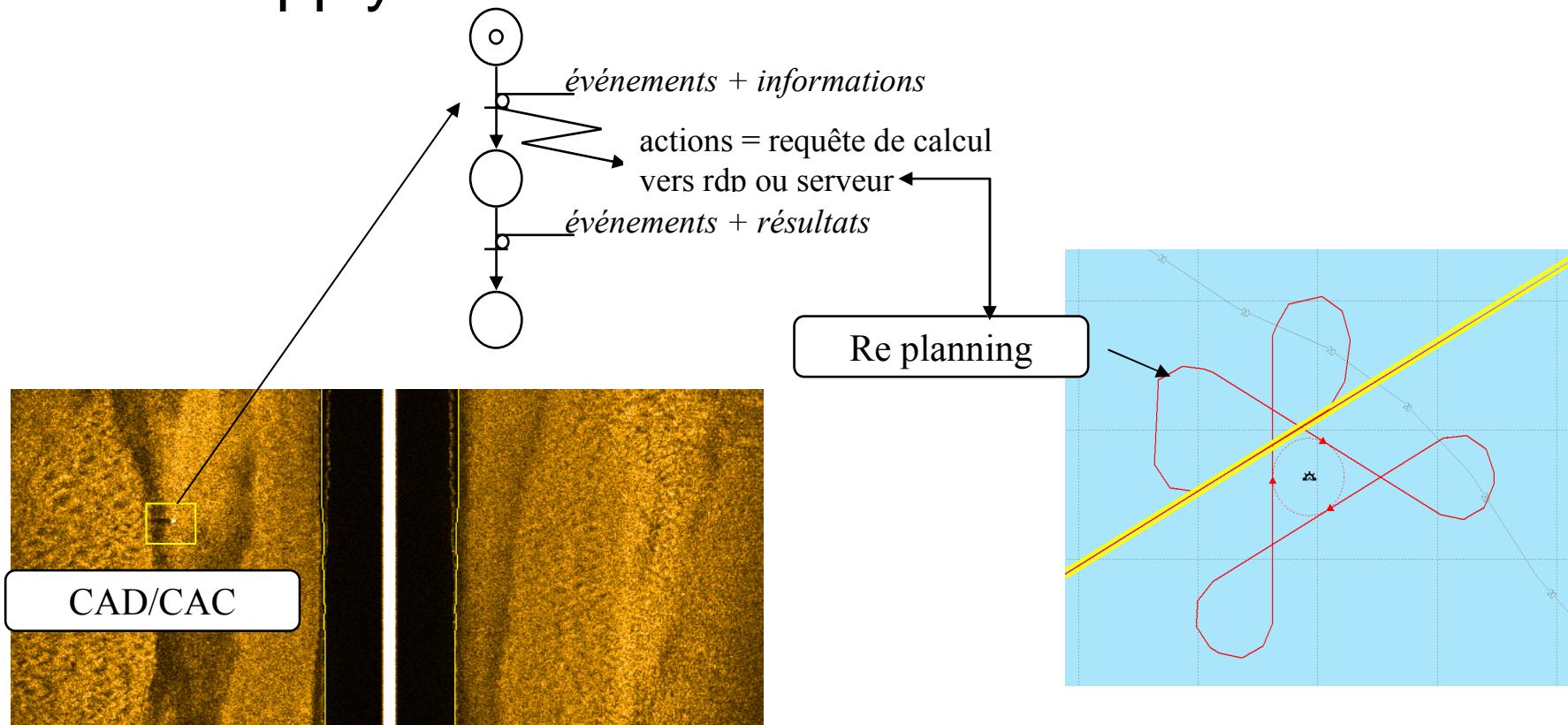
Supervision by Petri nets

Events generation, data treatment

- **Apply to mine warfare**

événements + informations

actions = requête de calcul
vers rdp ou serveur

événements + résultats

Re planning

CAD/CAC
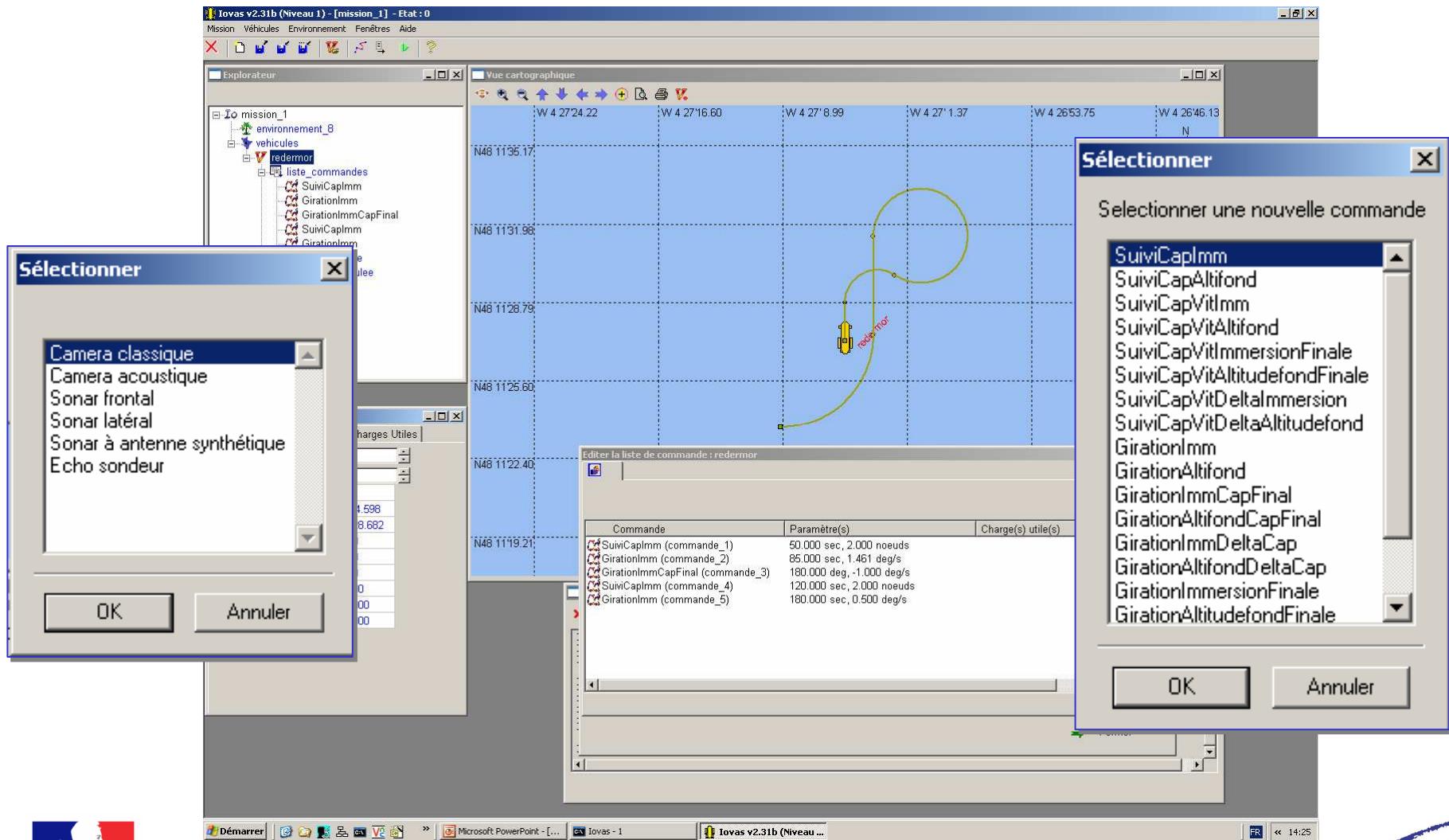
Level 1 : IOVAS MMI (Prolexia)

Level 1 : sequence of controls

Level 1 : mission script

Level 1 : controls

Type de commande	Paramètres										
	durée	vitesse_avance	immersion_finale	vitesse_chgt_immersion	altitudefond_finale	vitesse_chgt_altitudefond	delta_immersion	delta_altitudefond	vitesse_giration	cap_final	delta_cap
SuiviCapVitImm	x										
SuiviCapVitAltifond	x										
SuiviCapImm	x	x									
SuiviCapAltifond	x	x									
SuiviCapVitImmersionFinale			x	x							
SuiviCapVitAltitudefondFinale					x	x					
SuiviCapVitDeltaImmersion				x			x				
SuiviCapVitDeltaAltitudefond						x		x			
GirationImm	x								x		
GirationAltifond	x								x		
GirationImmCapFinal									x	x	
GirationAltifondCapFinal									x	x	
GirationImmDeltaCap									x		x
GirationAltifondDeltaCap									x		x
GirationImmersionFinale			x	x					x		
GirationAltitudefondFinale					x	x			x		
GirationDeltaImmersion				x			x		x		
GirationDeltaAltitudefond						x		x	x		

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Level 1: supervision
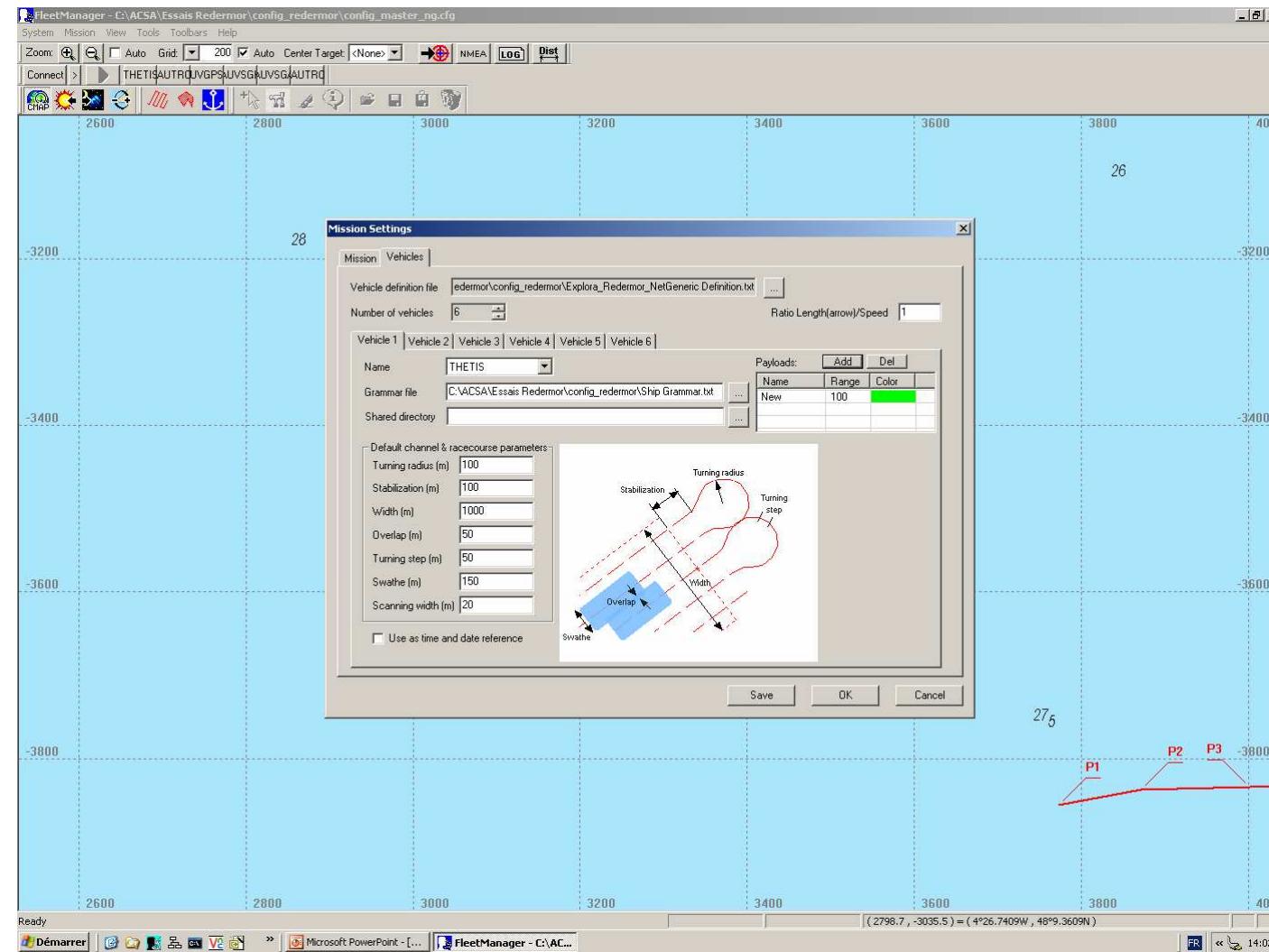
Level 2 MMI : Fleet manager (ACSA)
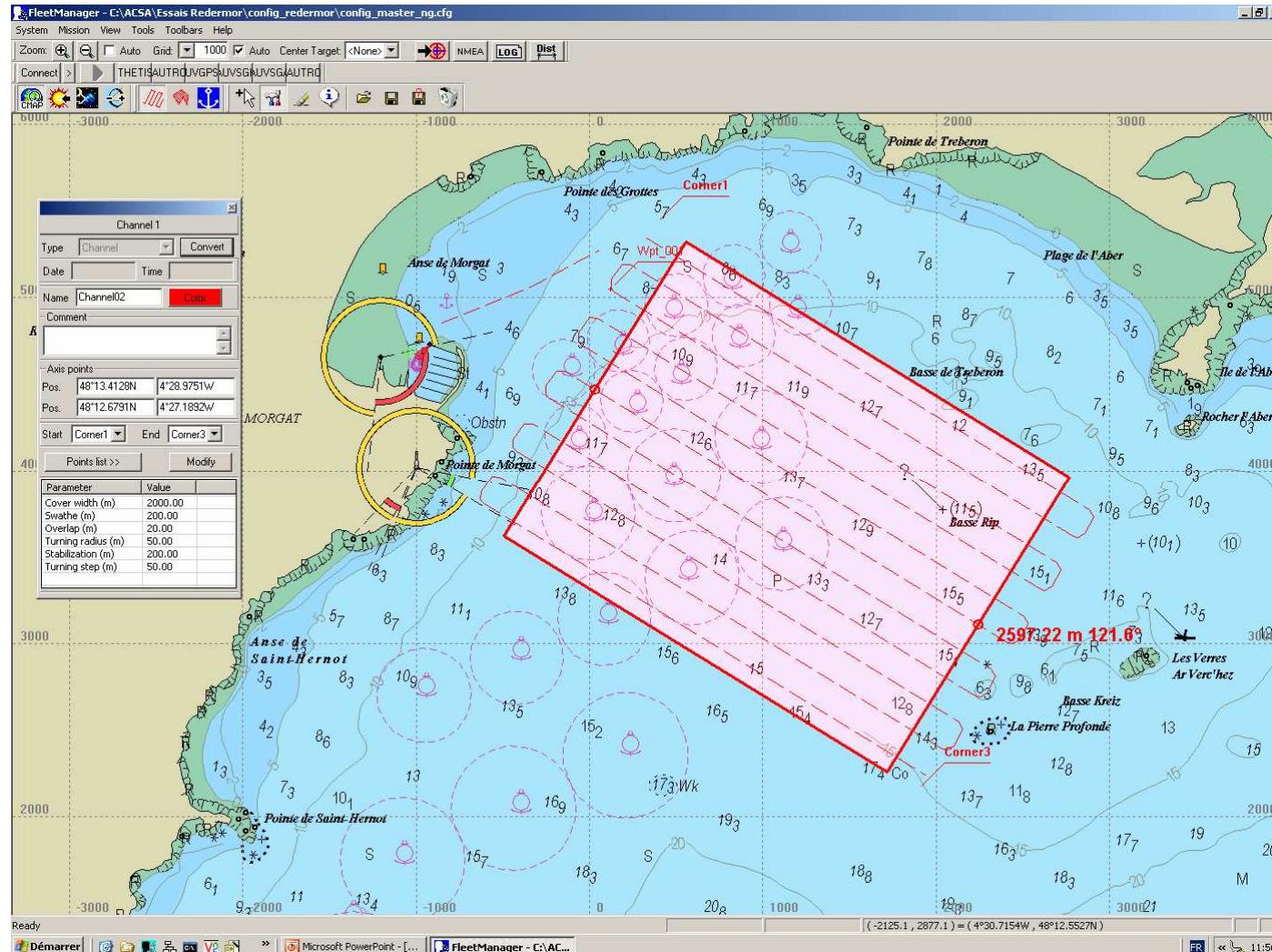
Level 2: what an AUV can do?
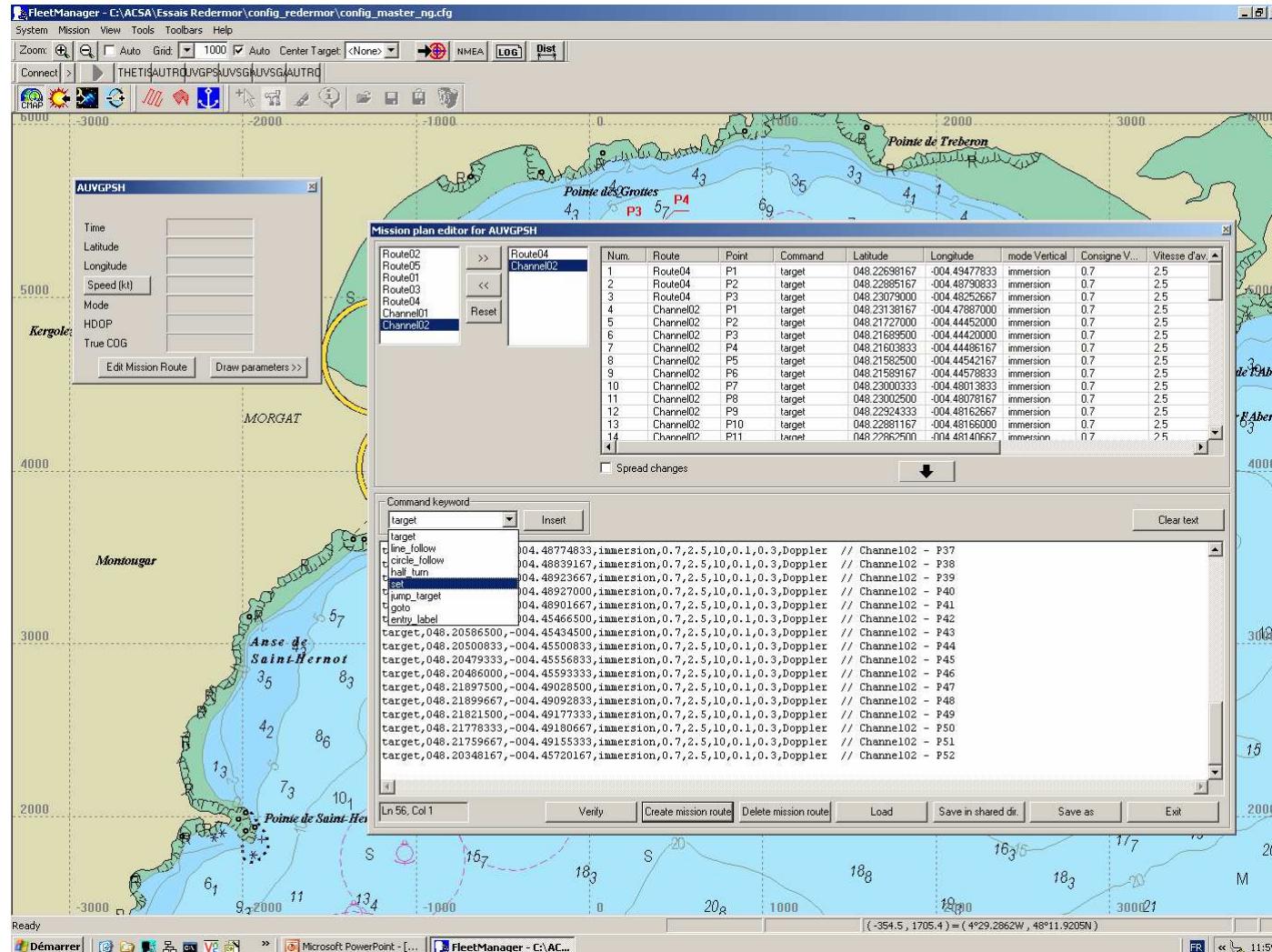
# Level 2 : waypoints definition
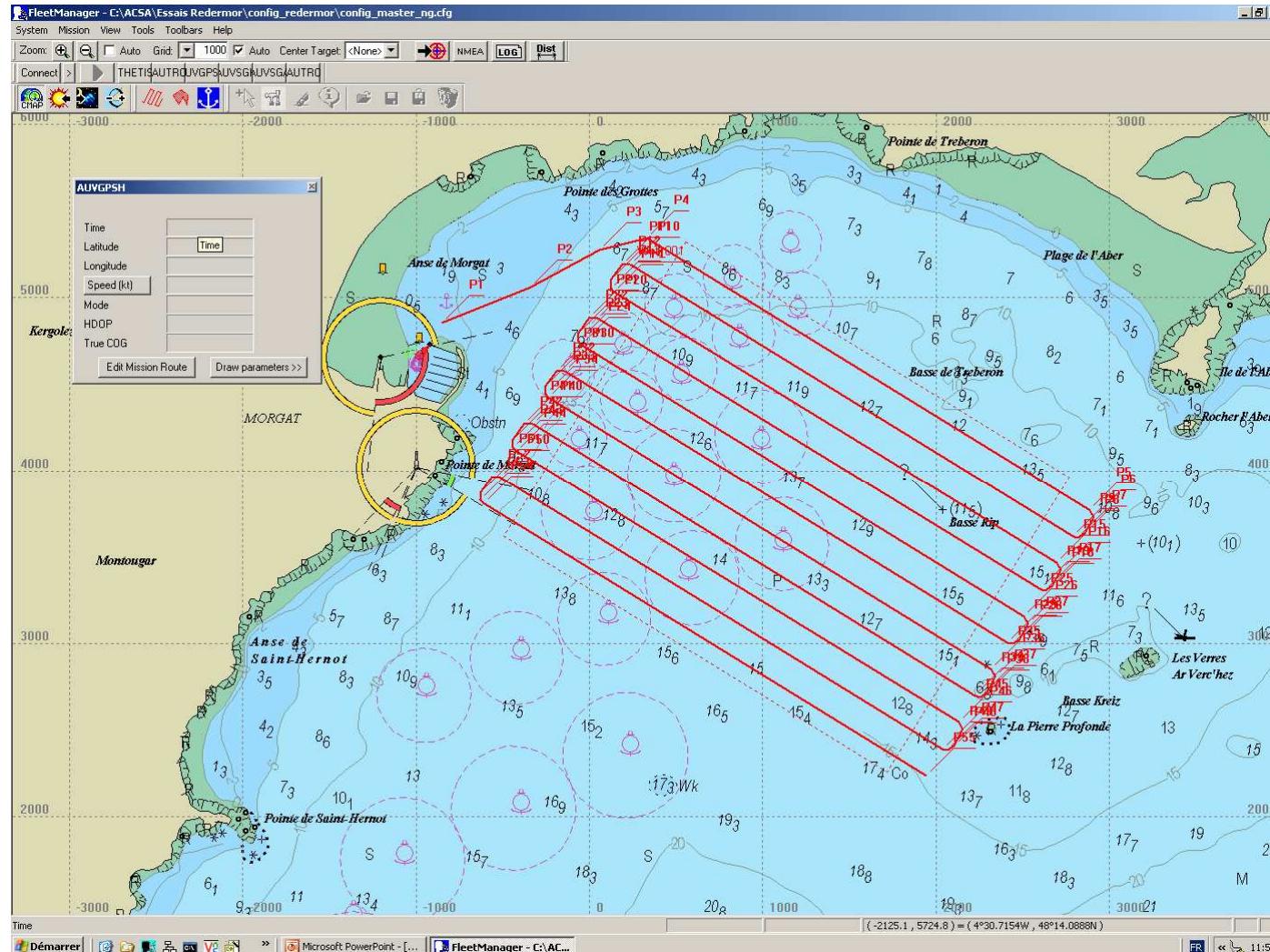
Level 2 : mission script
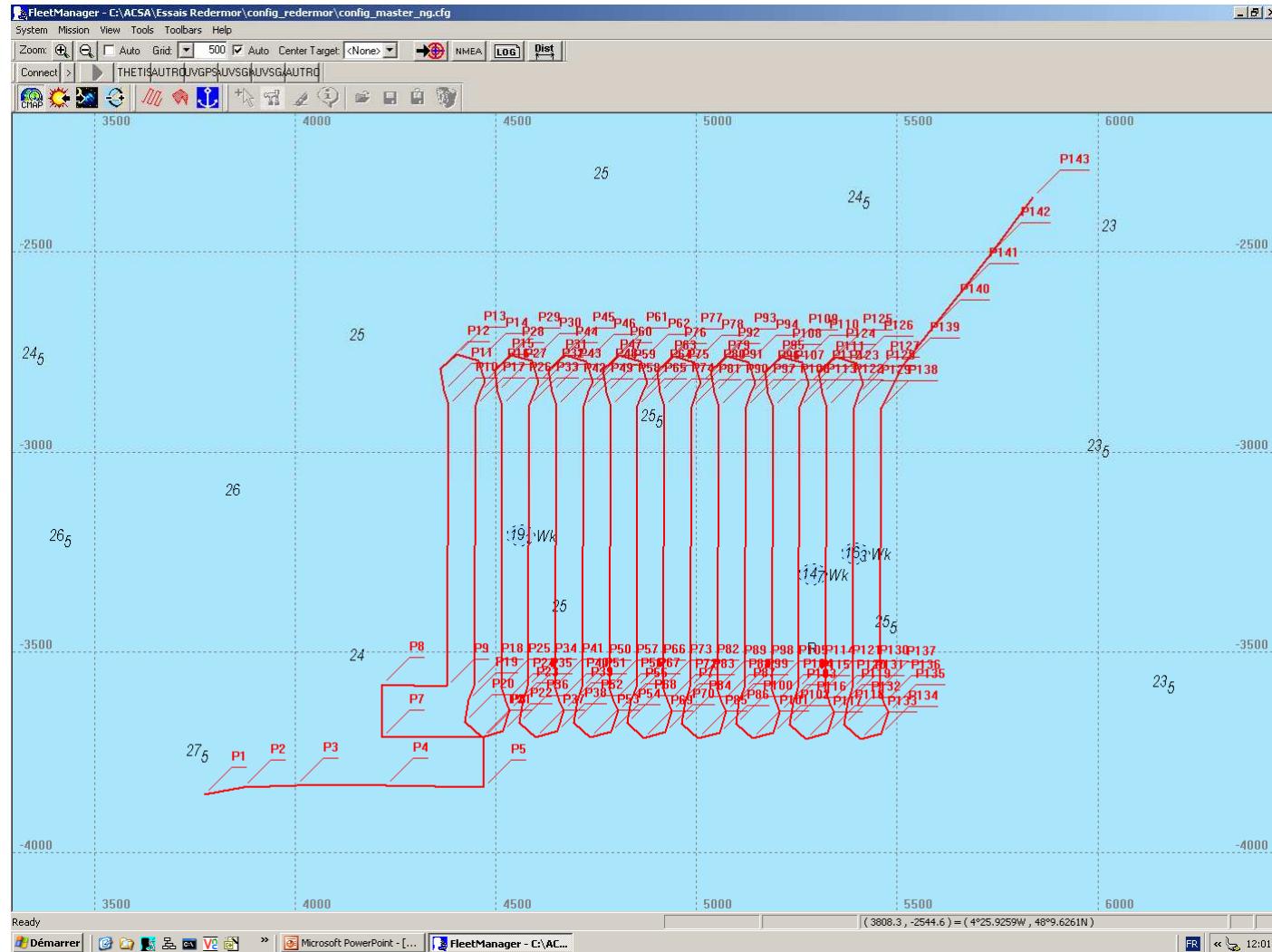
Level 2: mission supervision

Level 2 : mission example

Level 2 : mission script example


```
Command keyword
[target ▼]  [Insert]                                                          [Clear text]

target,048.14864167,-004.43257667,immersion,0.7,2.5,10,0.1,0.3,Doppler   // Route01 - P1
target,048.14880500,-004.43125833,immersion,5.0,2.5,10,0.1,0.3,Doppler   // Route01 - P2
target,048.14883833,-004.42950000,altitude,10.0,2.5,10,0.1,0.3,Doppler   // Route01 - P3
target,048.14883833,-004.42647000,altitude,10.0,2.5,10,0.1,0.3,Doppler   // Route01 - P4
target,048.14880500,-004.42319833,altitude,10.0,2.5,10,0.1,0.3,Doppler   // Route01 - P5
target,048.14991667,-004.42319833,altitude,10.0,2.5,10,0.1,0.3,Doppler   // Route01 - P6
set,RESON,ON,0,0,0,0,0
target,048.14991667,-004.42661667,altitude,10.0,2.5,10,0.1,0.3,Doppler   // Route01 - P7
target,048.15109333,-004.42661667,altitude,10.0,2.5,10,0.1,0.3,Doppler   // Route01 - P8
target,048.15106500,-004.42445000,altitude,10.0,2.5,10,0.1,0.3,Doppler   // Channel01 - P1
set,KLEIN,ACQ,0,0,0,0,0
target,048.15739333,-004.42439167,altitude,10.0,2.5,10,0.1,0.3,Doppler   // Channel01 - P2
set,KLEIN,ON,0,0,0,0,0
target,048.15770833,-004.42454833,altitude,10.0,2.5,10,0.1,0.3,Doppler   // Channel01 - P3
target,048.15819833,-004.42465667,altitude,10.0,2.5,10,0.1,0.3,Doppler   // Channel01 - P4
target,048.15852333,-004.42410000,altitude,10.0,2.5,10,0.1,0.3,Doppler   // Channel01 - P5
target,048.15838667,-004.42338833,altitude,10.0,2.5,10,0.1,0.3,Doppler   // Channel01 - P6

Ln 7, Col 1    [Verify] [Create mission route] [Delete mission route] [Load] [Save in shared dir.] [Save as] [Exit]
```
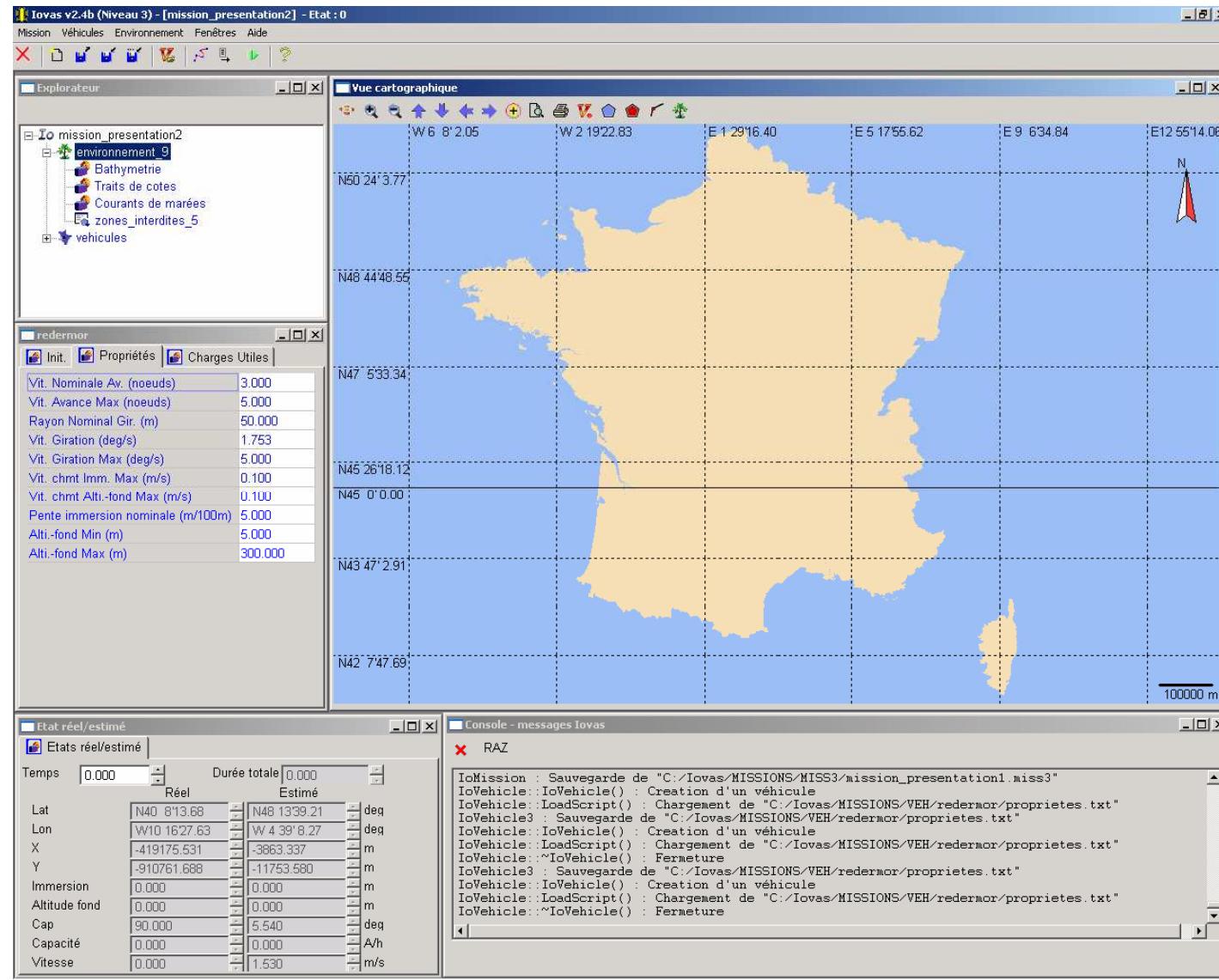
# Level 3 : IOVAS MMI (Prolexia)

Level 3 : IOVAS MMI
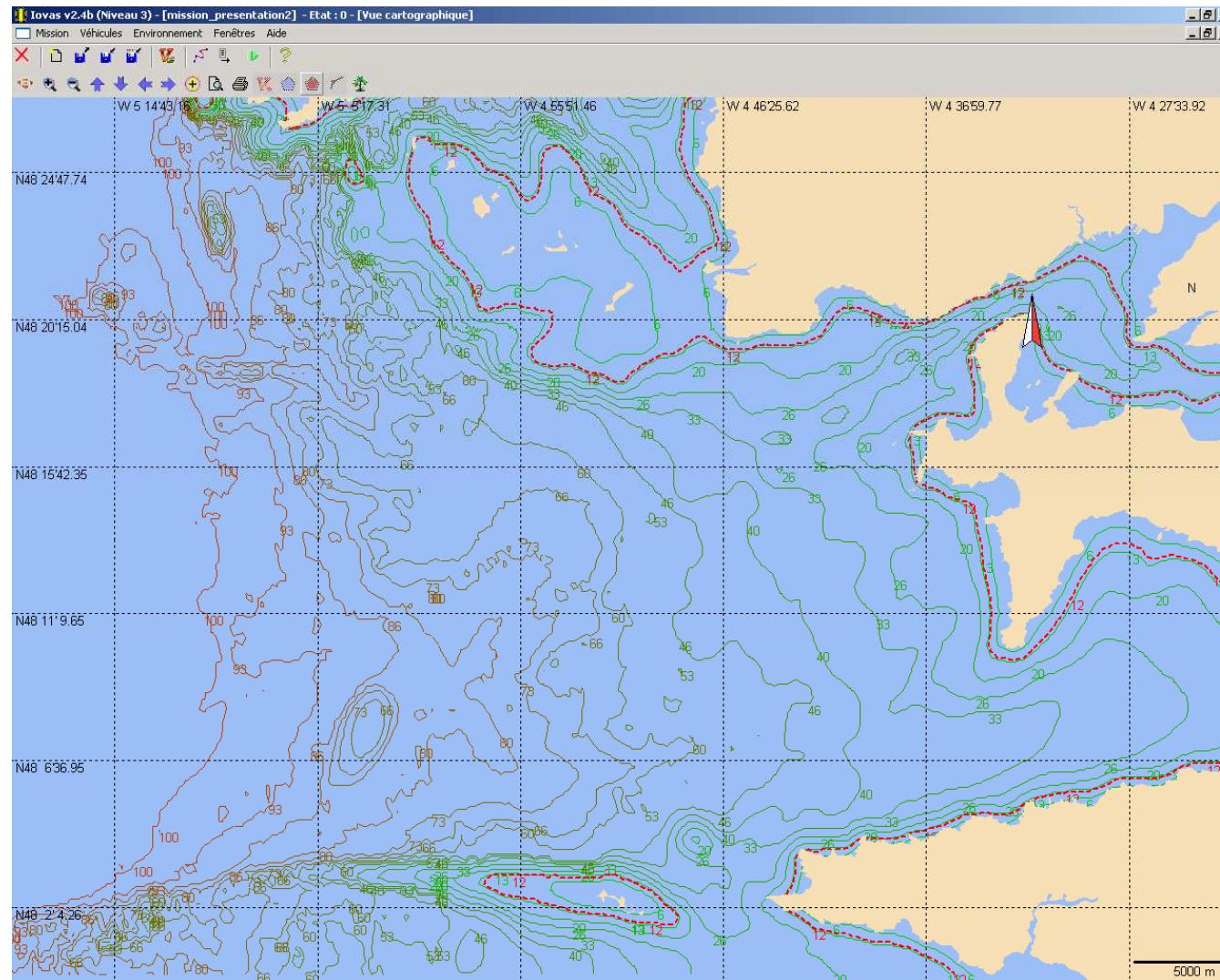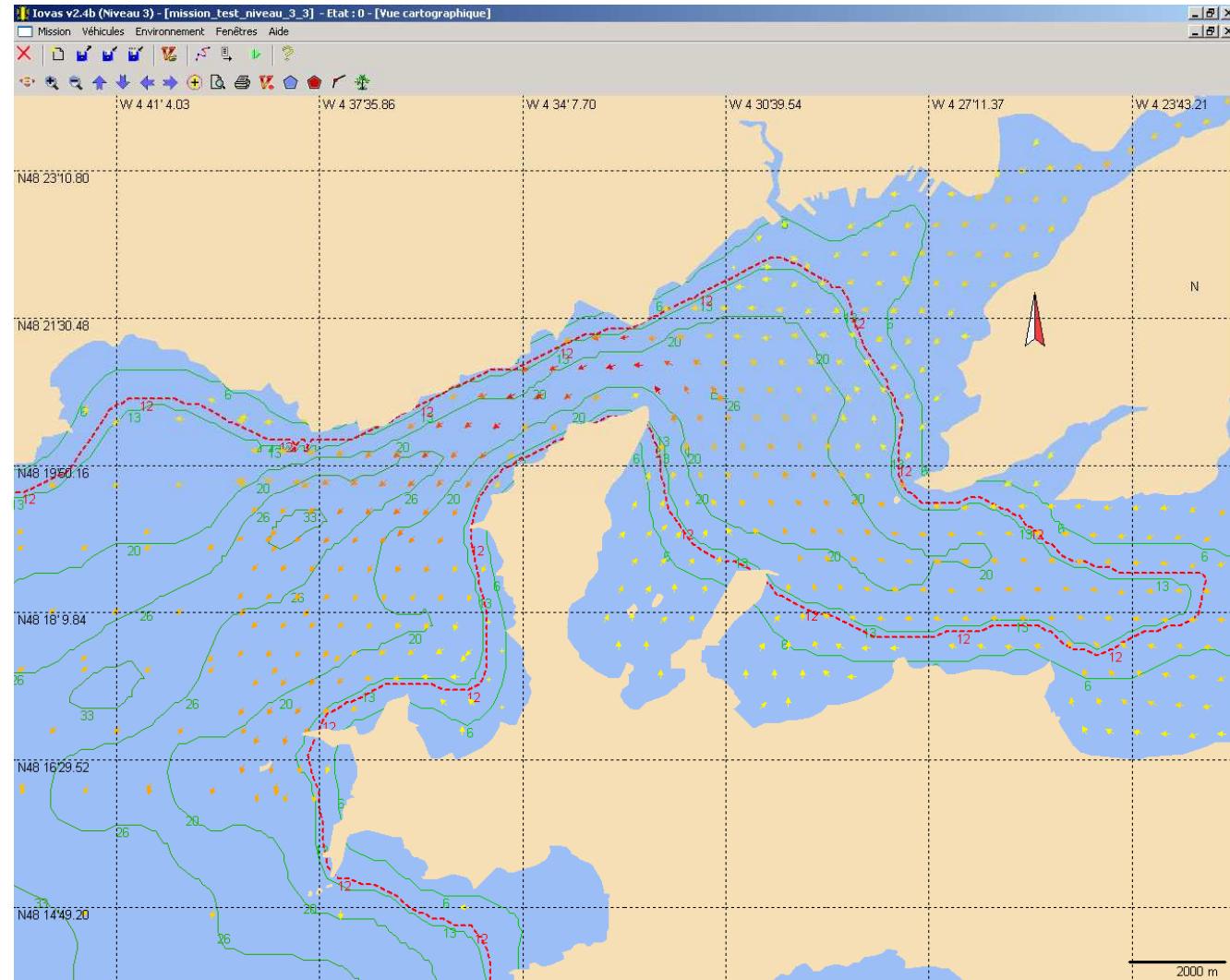
# Level 3 : interaction with environment
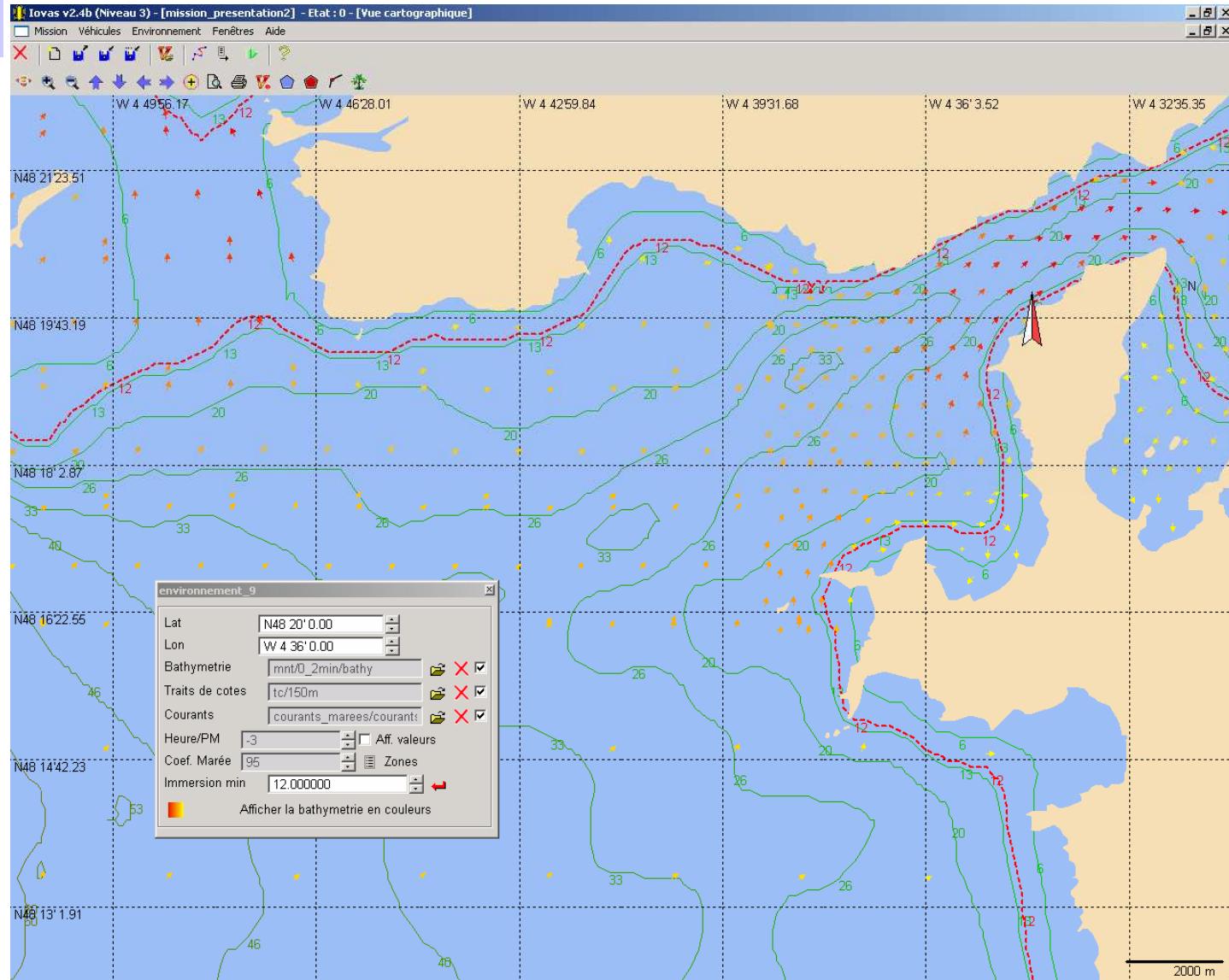
Level 3 : interaction with environment
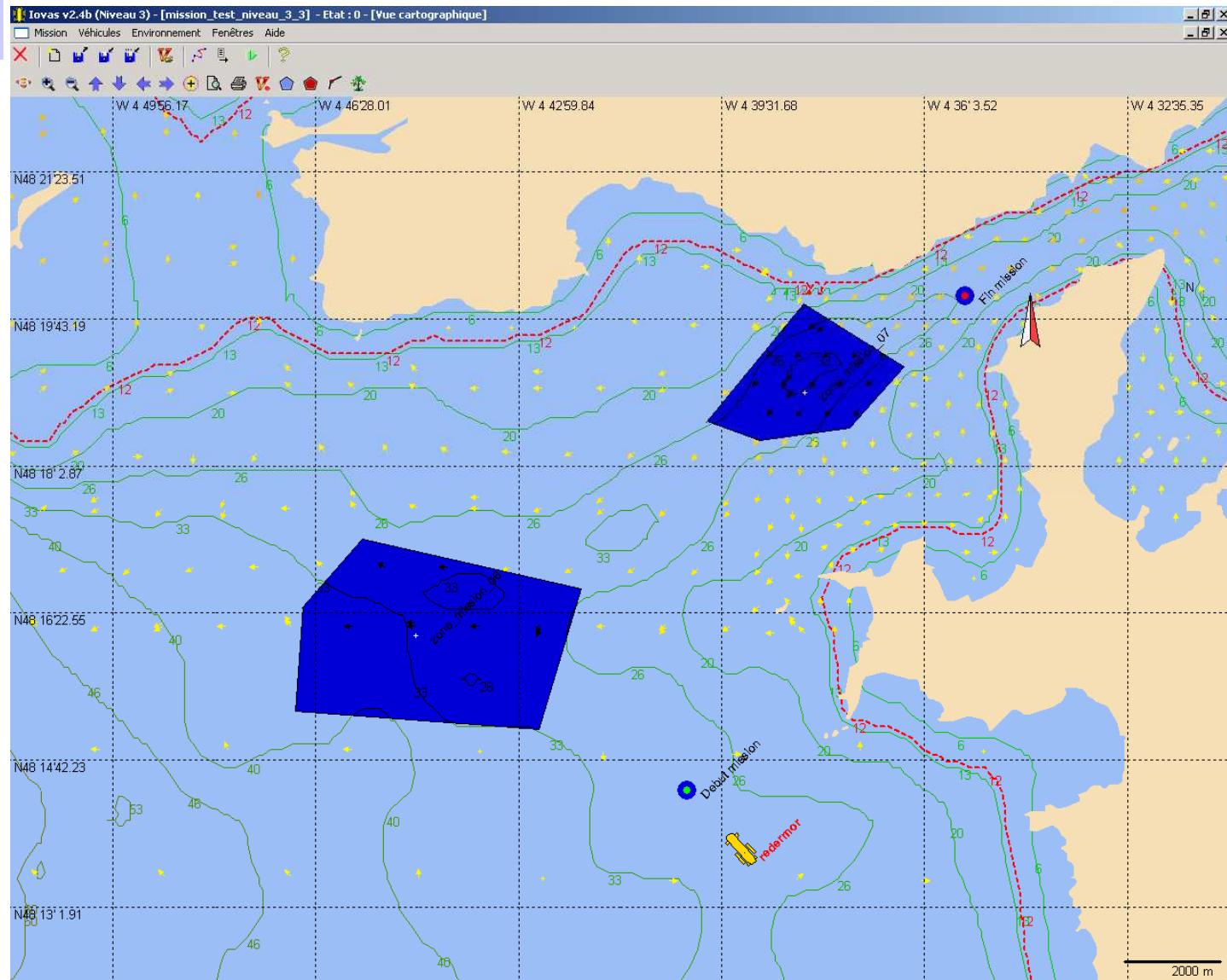
Level 3 : Mission preparation
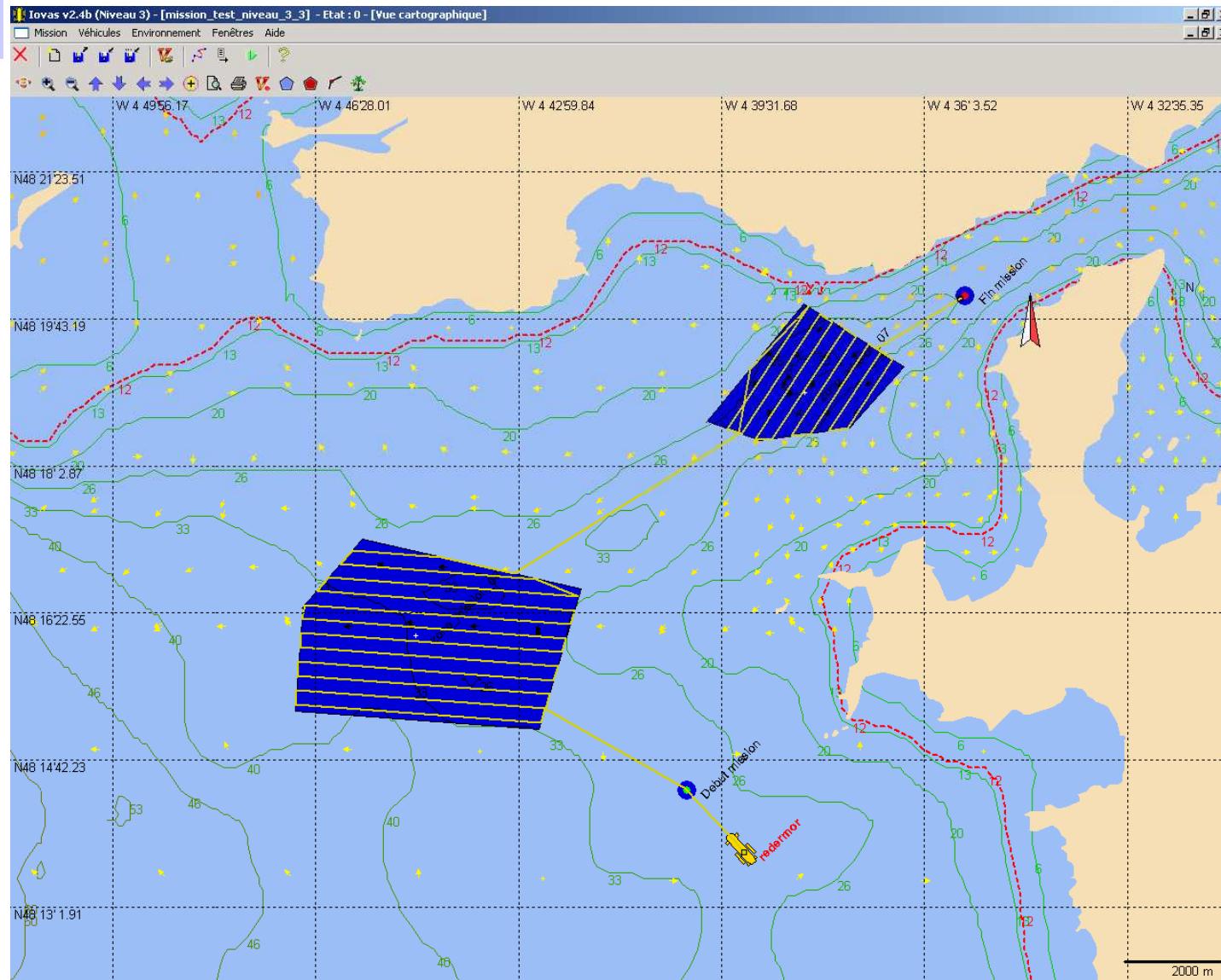
Level 3: Missions goals
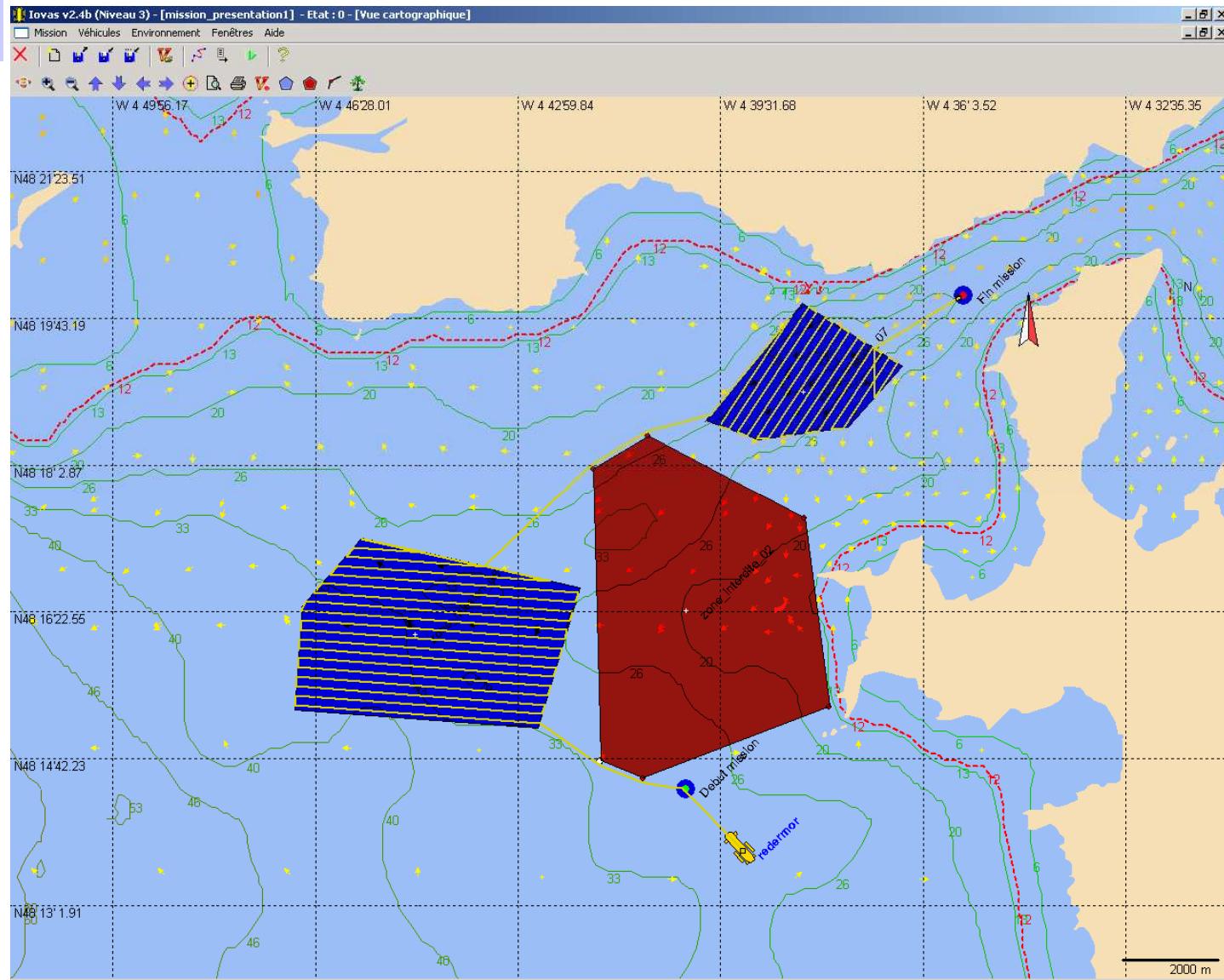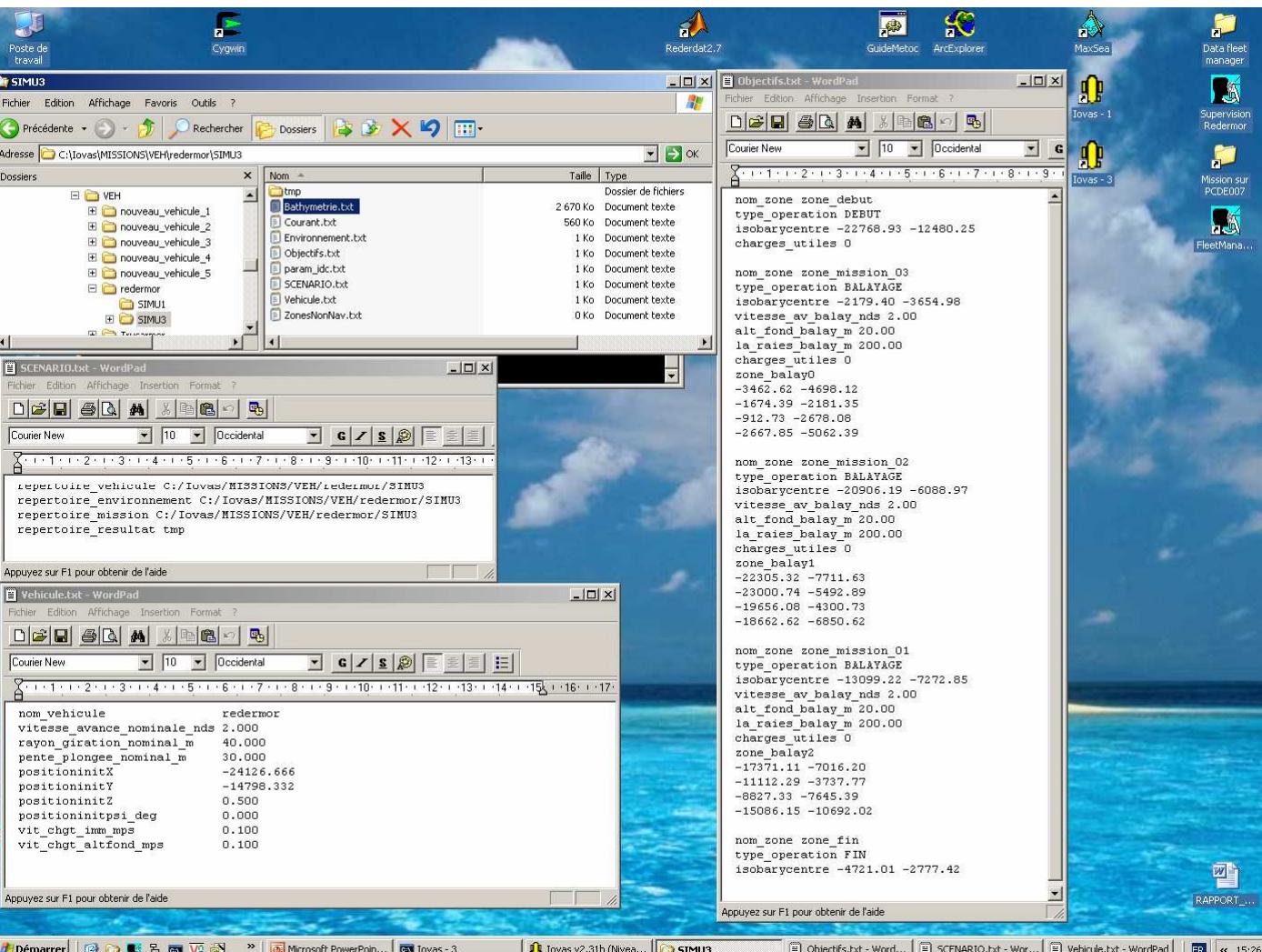
Level 3: Automatic planning

Level 3: Automatic planning

Level 3: mission script?
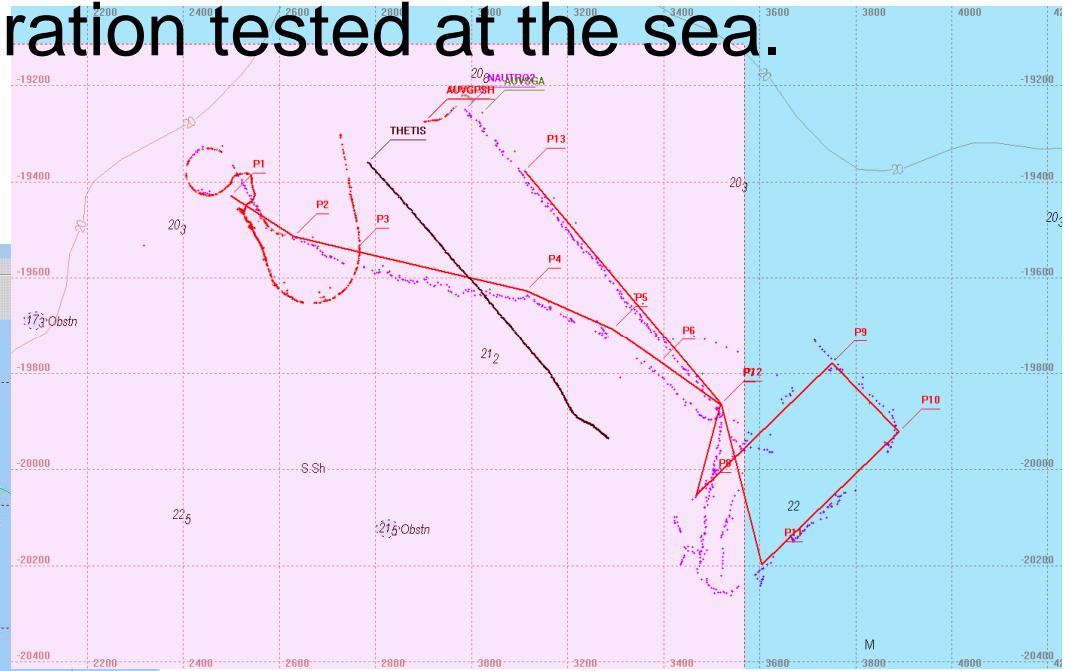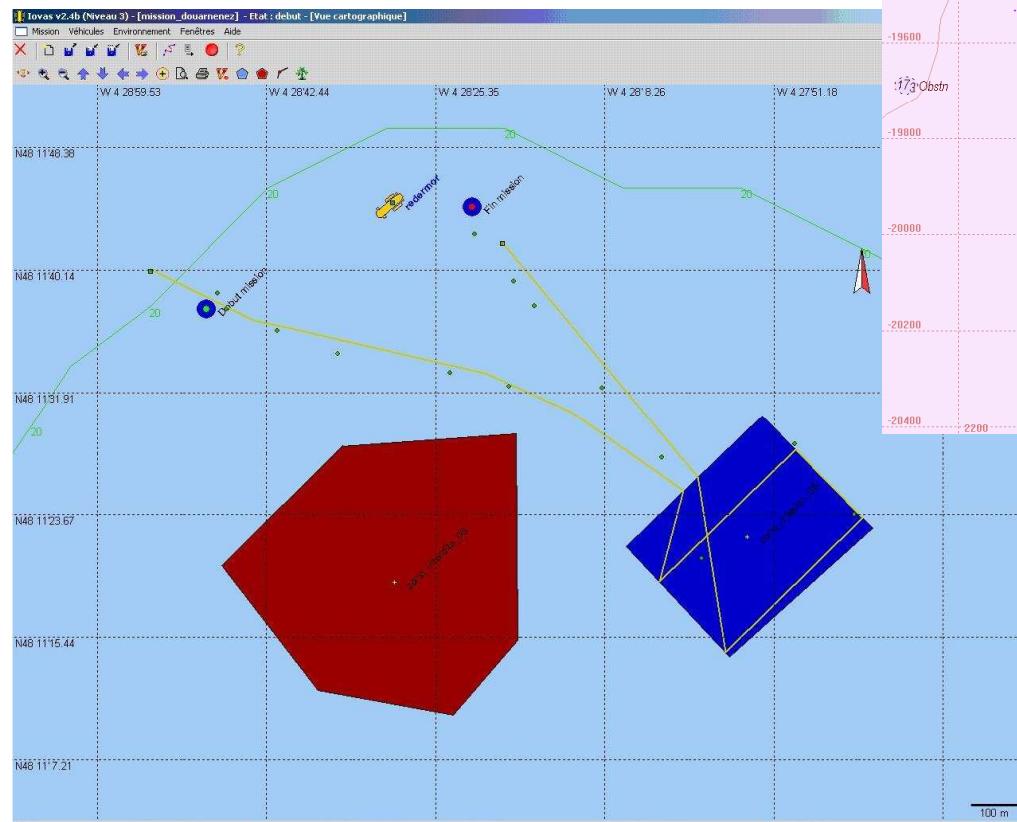
On-going test

- Level 1 and 2 :
  - fully operational

- Level 3:
  - tested in simulation,
  - at sea this year.

- Adaptivity to be tested :
  - Wrong current direction in the initial planning of a survey zone
  - Inspect (multi-aspect sonar acquisition) a contact

On-going test

Level 3 : Integration tested at the sea.

Further works

- Mine warfare: do sonar acquisition of the survey zone until the performance criteria is over a define threshold

- REA : Survey strategy with regards to sea bottom characteristics

- Optimization of long duration mission related to current and tide evolution

Conclusion

- Petri nets are a good solution for supervision and adaptivity

- Difficulty of environmental database integration

- Planning algorithm seemed not so complicated at first stage…