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RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE LA DÉFENSE

# Goal driven planning and adaptivity for AUVs

CAR06



DÉLÉGATION GÉNÉRALE POUR L'ARMEMENT



# GESMA : Location





# GESMA : Skills & Missions

Mine warfare

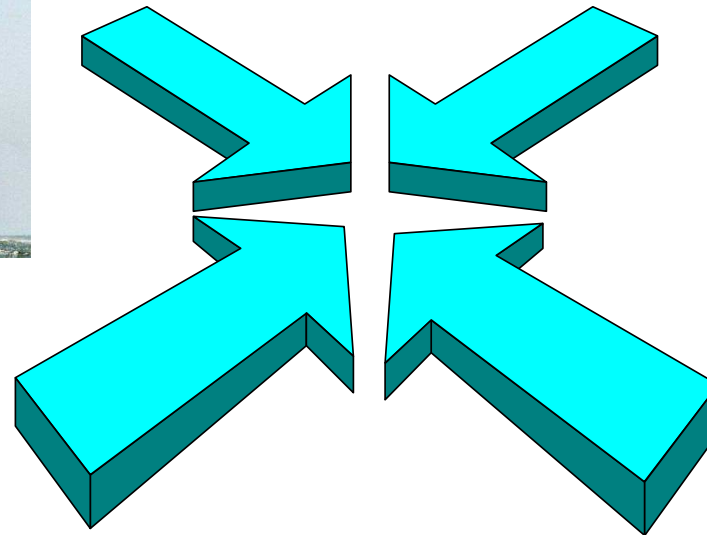
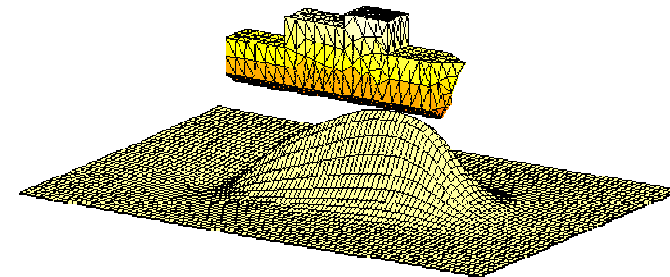


Underwater Warfare Environment

Robotics



Platform susceptibility



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06/04/2006

Diapositive N°3 / 46





**GESMA**



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# ONERA : French Aeronautics and Space Research Center

DCSD Lab: Systems Control and Flight Dynamics Department

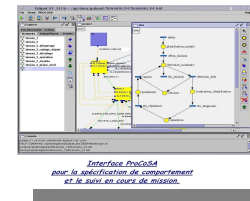
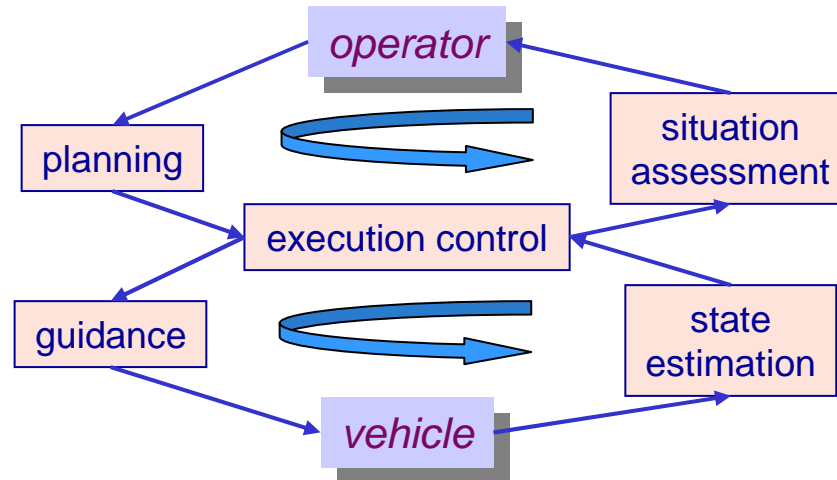
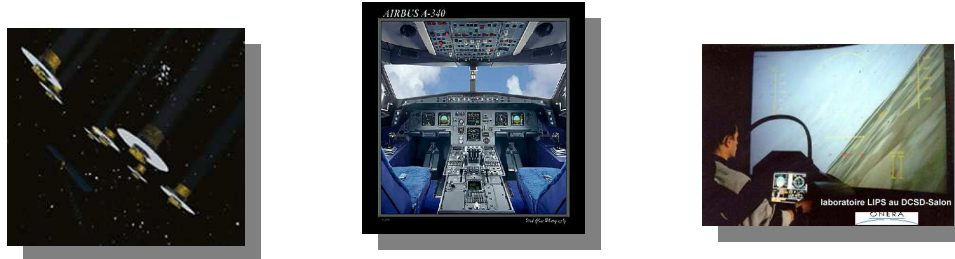
ONERA

Human Factors

Decision

Control

Flight mechanics & Identification





# PROLEXIA

- Small company
- Simulation
- Mission planning tools



*Prolexia*

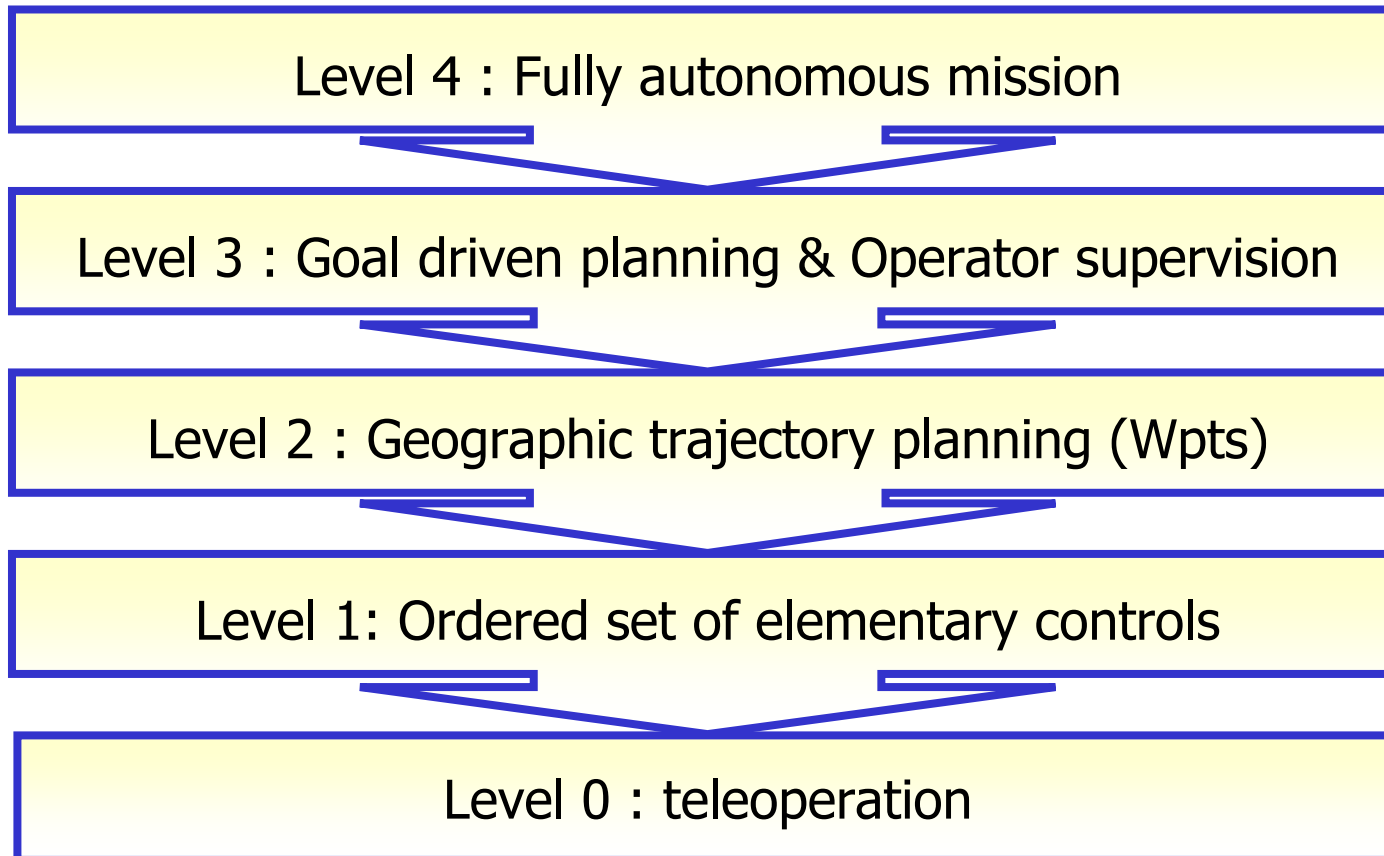


# Gesma studies on planning tools

- Assess requirements for mission planning tools for different levels of autonomy
- Assess adaptivity for Mine Warfare and REA missions



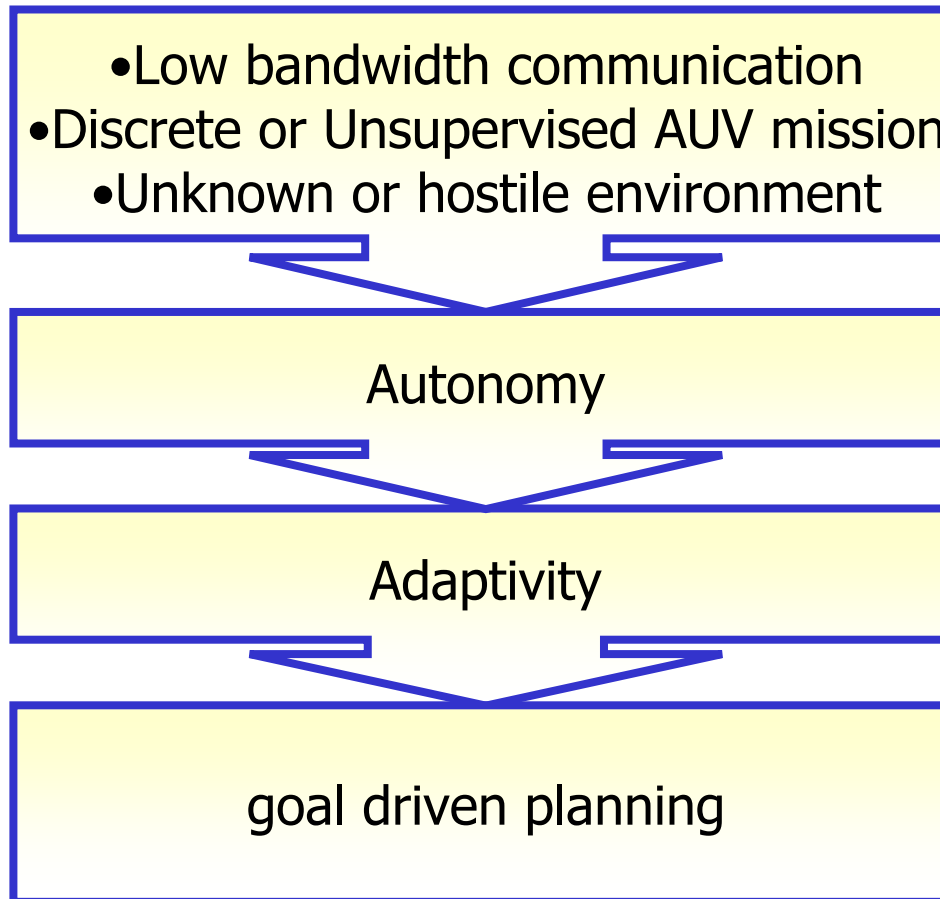
# Levels of autonomy







# Military requirements





## 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 classified, try to identify by going over at low altitude
- If enter a position 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

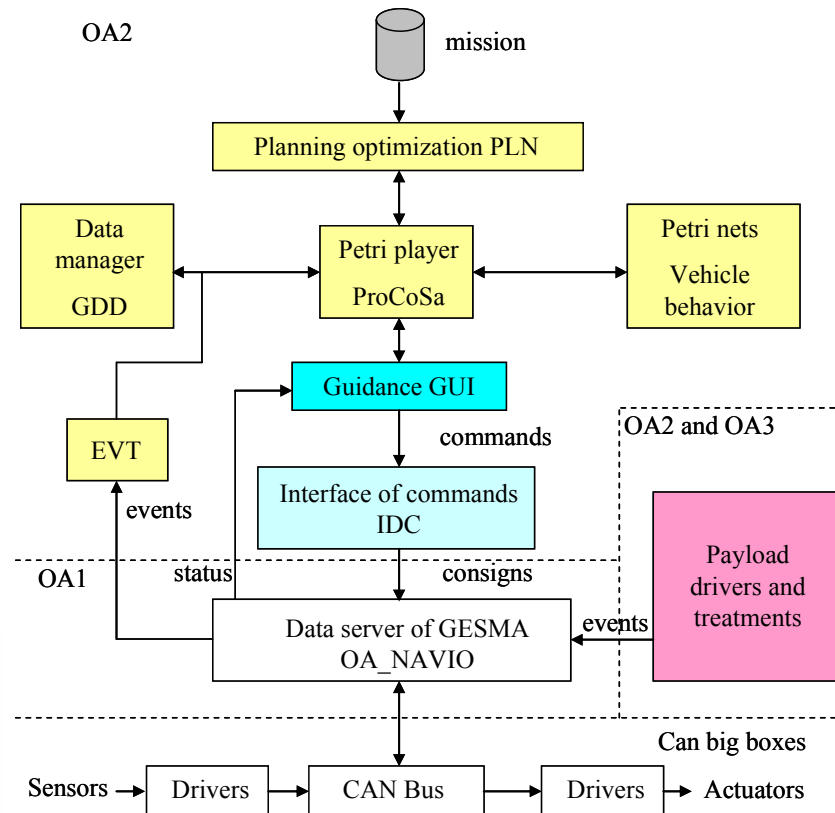
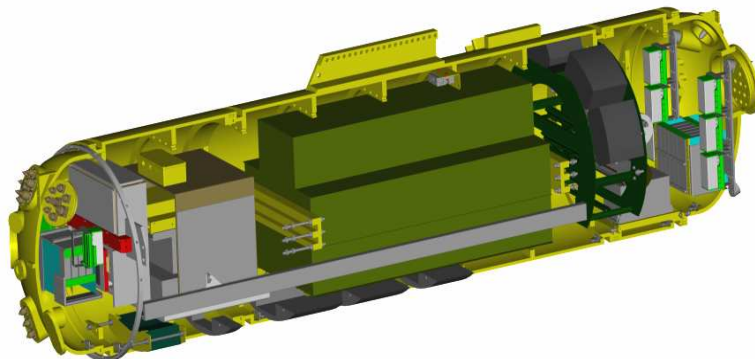
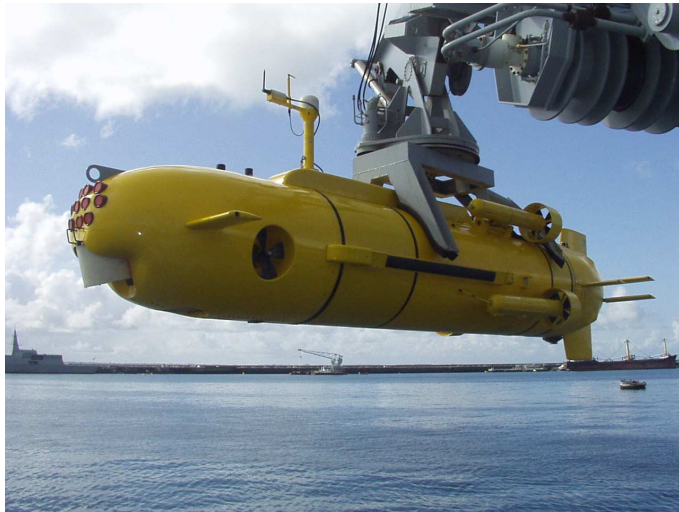


## What you need is:

- 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



# The nice AUV : Redermor





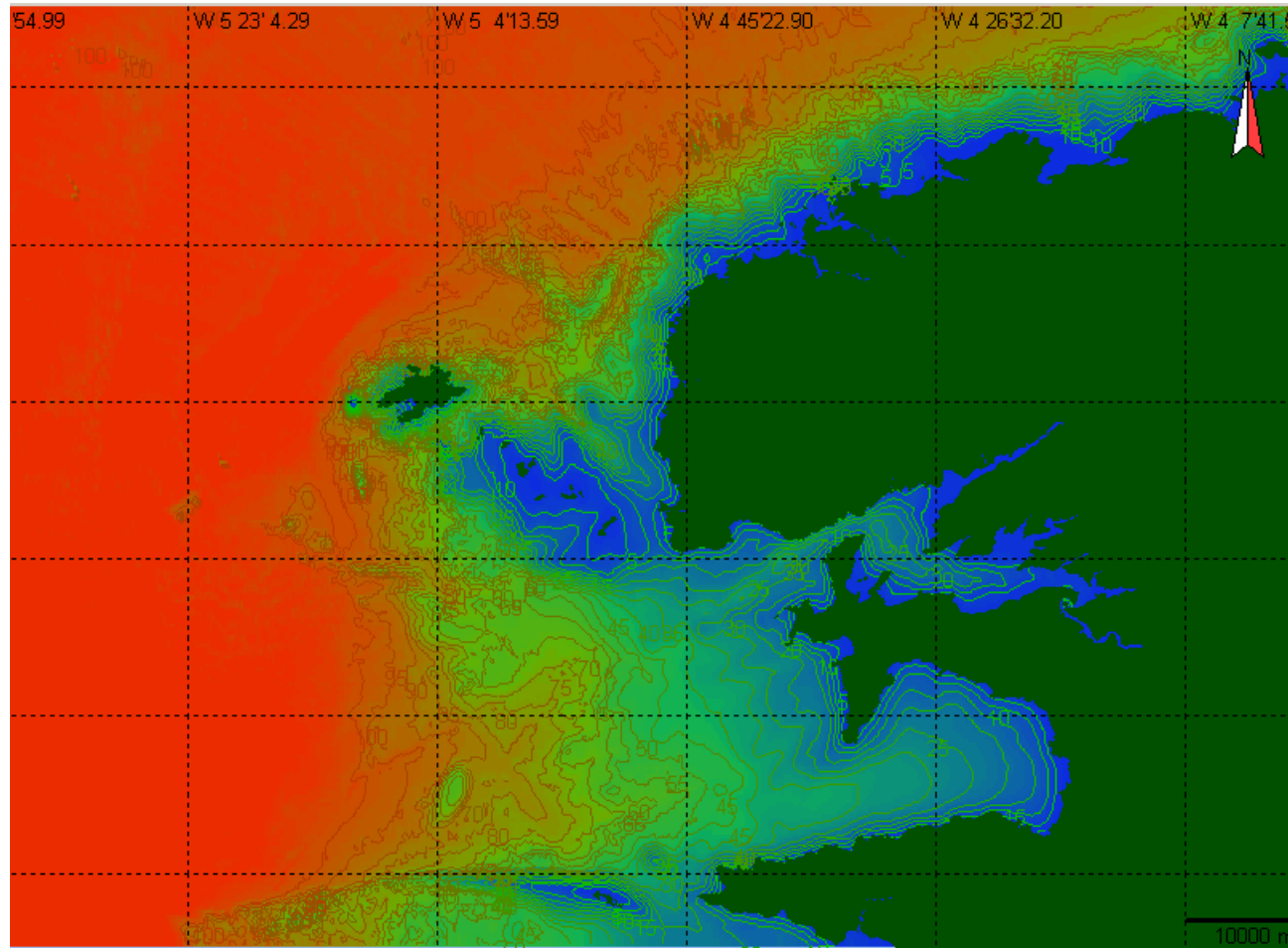
# Mission planning MMI

- level 1 : text editor Or NIVAS/IOVAS
- level 2 : FLEET MANAGER
- level 3 and 4 : NIVAS/IOVAS





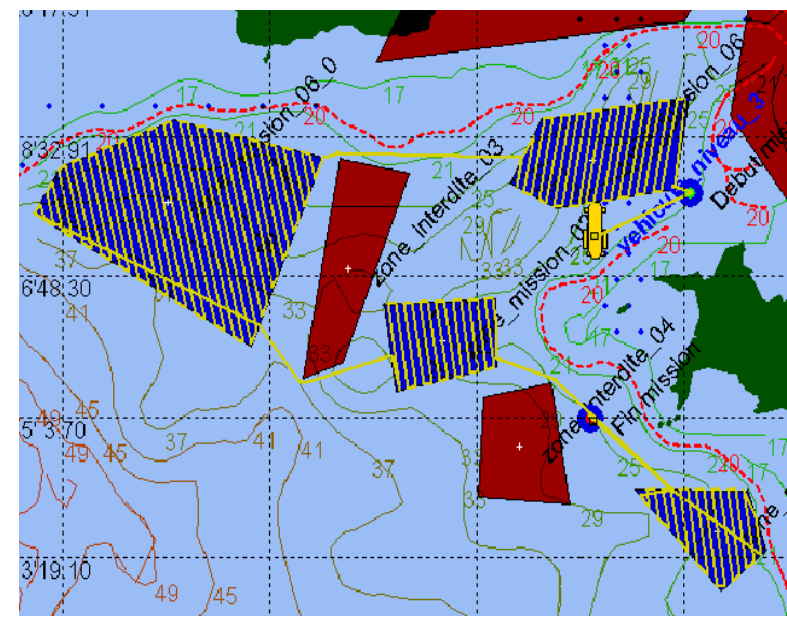
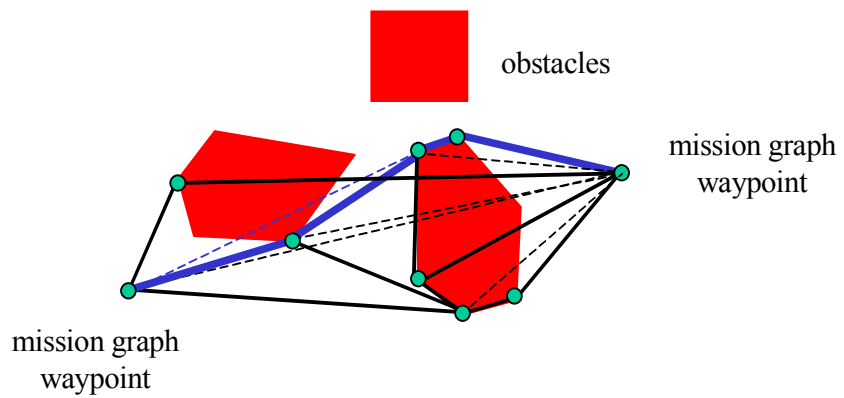
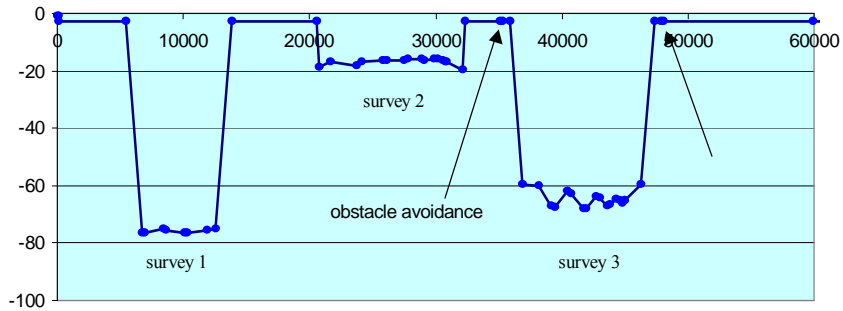
# Environmental database





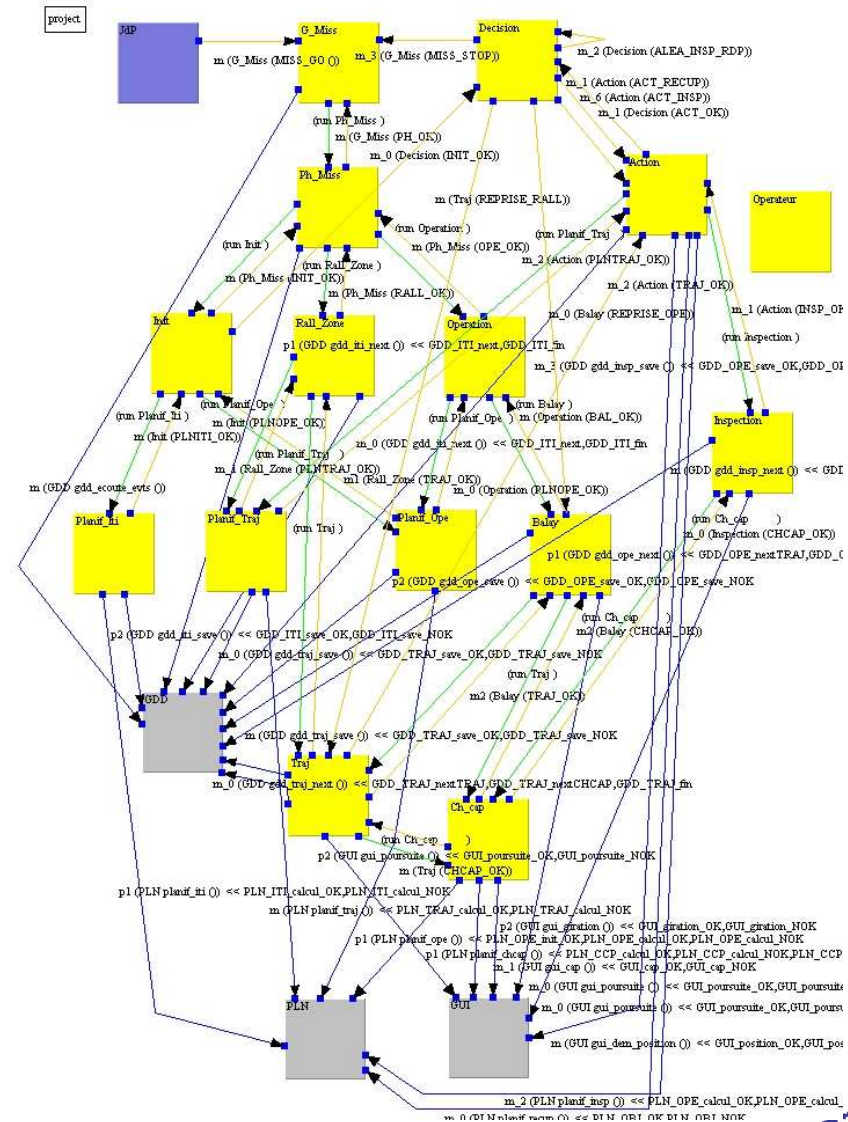
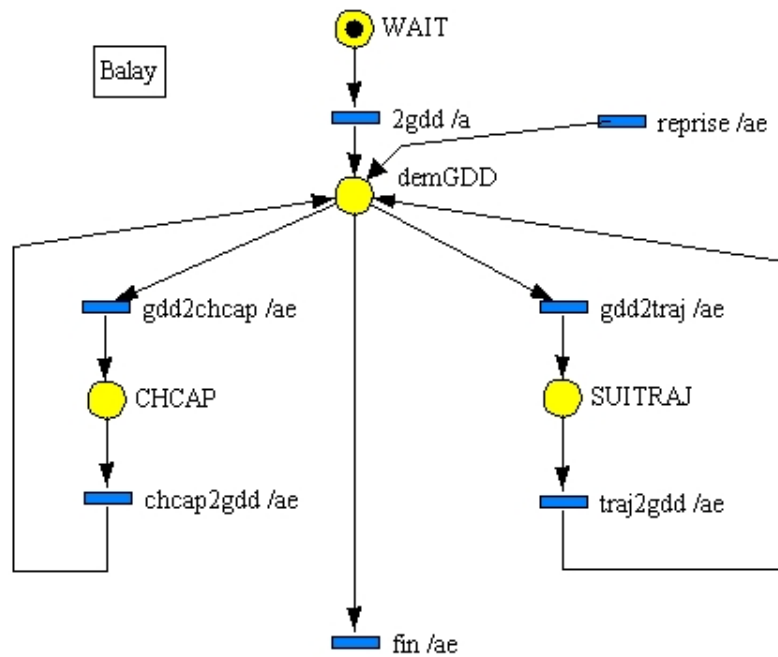


# Planning algorithms





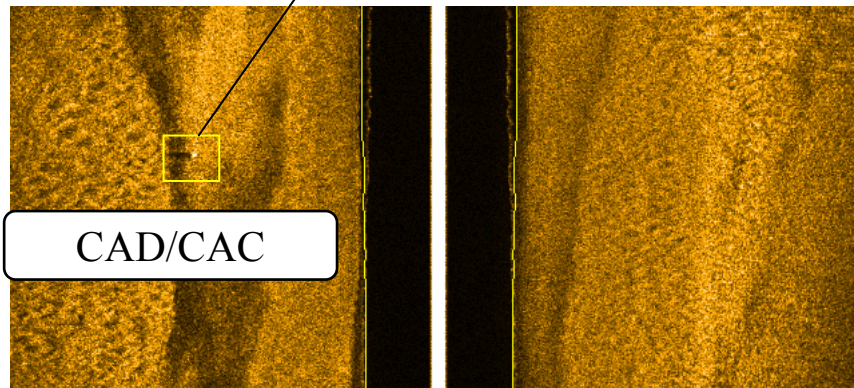
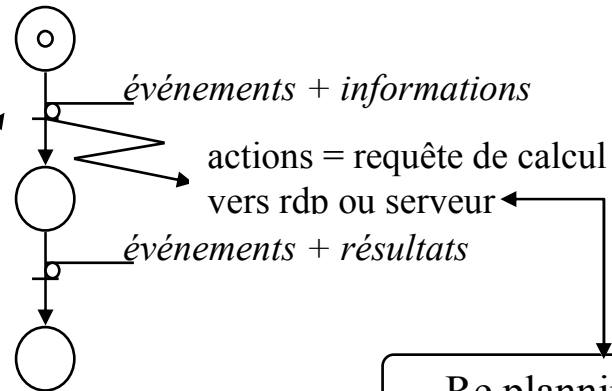
# Supervision by Petri nets



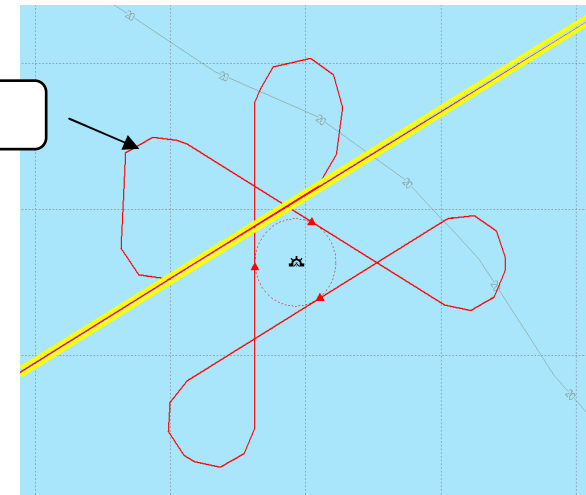


# Events generation, data treatment

- Apply to mine warfare



Re planning





# Level 1 : IOVAS MMI (Prolexia)

**I O V A S**  
Interface Opérateur pour Véhicule Autonome Sous-marin

**ONERA**  
Office National d'Études et de Recherches Aérospatiales  
CENTRE DE TOULOUSE



# Level 1 : sequence of controls

**Sélectionner**

Selectionner une nouvelle commande

- SuiviCapImm
- SuiviCapAltifond
- SuiviCapVitImm
- SuiviCapVitAltifond
- SuiviCapVitImmersionFinale
- SuiviCapVitAltitudefondFinale
- SuiviCapVitDeltaImmersion
- SuiviCapVitDeltaAltitudefond
- GirationImm
- GirationAltifond
- GirationImmCapFinal
- GirationAltifondCapFinal
- GirationImmDeltaCap
- GirationAltifondDeltaCap
- GirationImmersionFinale
- GirationAltitudefondFinale

**Editer la liste de commande : redarmor**

Commande	Paramètre(s)	Charge(s) utile(s)
SuiviCapImm (commande_1)	60.000 sec, 2.000 noeuds	
GirationImm (commande_2)	85.000 sec, 1.461 deg/s	
GirationImmCapFinal (commande_3)	180.000 deg, -1.000 deg/s	
SuiviCapImm (commande_4)	120.000 sec, 2.000 noeuds	
GirationImm (commande_5)	180.000 sec, 0.500 deg/s	



# Level 1 : mission script

The screenshot displays a Windows XP desktop environment. At the top, a file explorer window titled 'SIMU1' is open, showing the directory structure of 'C:\Iovas\MISSIONS\VEH\redermor\SIMU1'. The 'Dossiers' pane shows a tree view with folders like 'Iovas', 'bin', 'DATA\_SHOM', 'MISSIONS', 'BIB', 'ENV', 'MIS51', 'MIS53', 'VEH', 'nouveau\_vehicule\_1', 'nouveau\_vehicule\_2', 'redermor', 'SIMU1', and 'SIMU3'. The 'Nom' pane lists three files: 'EffetL.Cdes.txt' (87 Ko, Document texte), 'LCommandes.txt' (1 Ko, Document texte), and 'param\_idc.txt' (1 Ko, Document texte).

Below the file explorer, two WordPad windows are open. The left window, titled 'param\_idc.txt - WordPad', displays the following text:

```
acc_avance_max_mps2      0.25
acc_chgt_imm_max_mps2    0.1
acc_chgt_altifond_max_mps2 0.1
acc_giration_max_degps2  2.0
lsb_cap_deg              0.1
lsb_immersion_m          0.1
lsb_altitdefond_m        0.1
lsb_vitesses_mps         0.001
consommation_vehicule     3.3 -0.47 3.6
pas_echantillonnage_IOV&S_s 1.0
```

The right window, titled 'LCommandes.txt - WordPad', displays the following text:

```
immersion_init_m        0.500
altitudefond_init_m     30.000
cap_init_deg            0.000
vitesse_initial_noeuds  0.000
tension_V               240.000
capacite_Ah             160.000
#
SuiviCapImm 50.000 2.000 0
GirationImm 85.000 1.461000 0
GirationImmCapFinal 180.000000 -1.000000 0
SuiviCapImm 120.000 2.000 0
GirationImm 180.000 0.500000 0
```



# 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		

# Level 1: supervision

**Explorateur**

- mission\_2
  - environnement\_2
  - vehicules
    - redemor
      - liste\_commande\_1
      - Trajectoire reelle
      - Trajectoire simulee

**redemor**

Propriétés

Lat : N48 1155.14  
 Lon : W 4 26'16.12

Type de véhicule : UUV  
 X initial (m) : 11976.295  
 Y initial (m) : -14967.642  
 Cap initial (deg) : /2.4UU  
 Vitesse initiale (noeuds) : 0.000  
 Immersion (m) : 0.000  
 Altitude fond (m) : 4.000  
 Tension (V) : 240.000  
 Capacité (A.h) : 0.000

**Etat réel/estimé**

	Réel	Estimé	
Temps	297.990	297.990	
Lat	N48 1155.21	N48 1154.86	deg
Lon	W 4 2553.94	W 4 2553.55	deg
X	12436.310	12444.449	m
Y	-14963.900	-14974.787	m
Immersion	1.800	-2.100	m
Altitude fond	24.500	1.200	m
Cap	119.290	119.990	deg
Capacité	21.000	-0.880	A/h
Vitesse	0.000	1.543	m/s

**Console - messages Iovos**

```

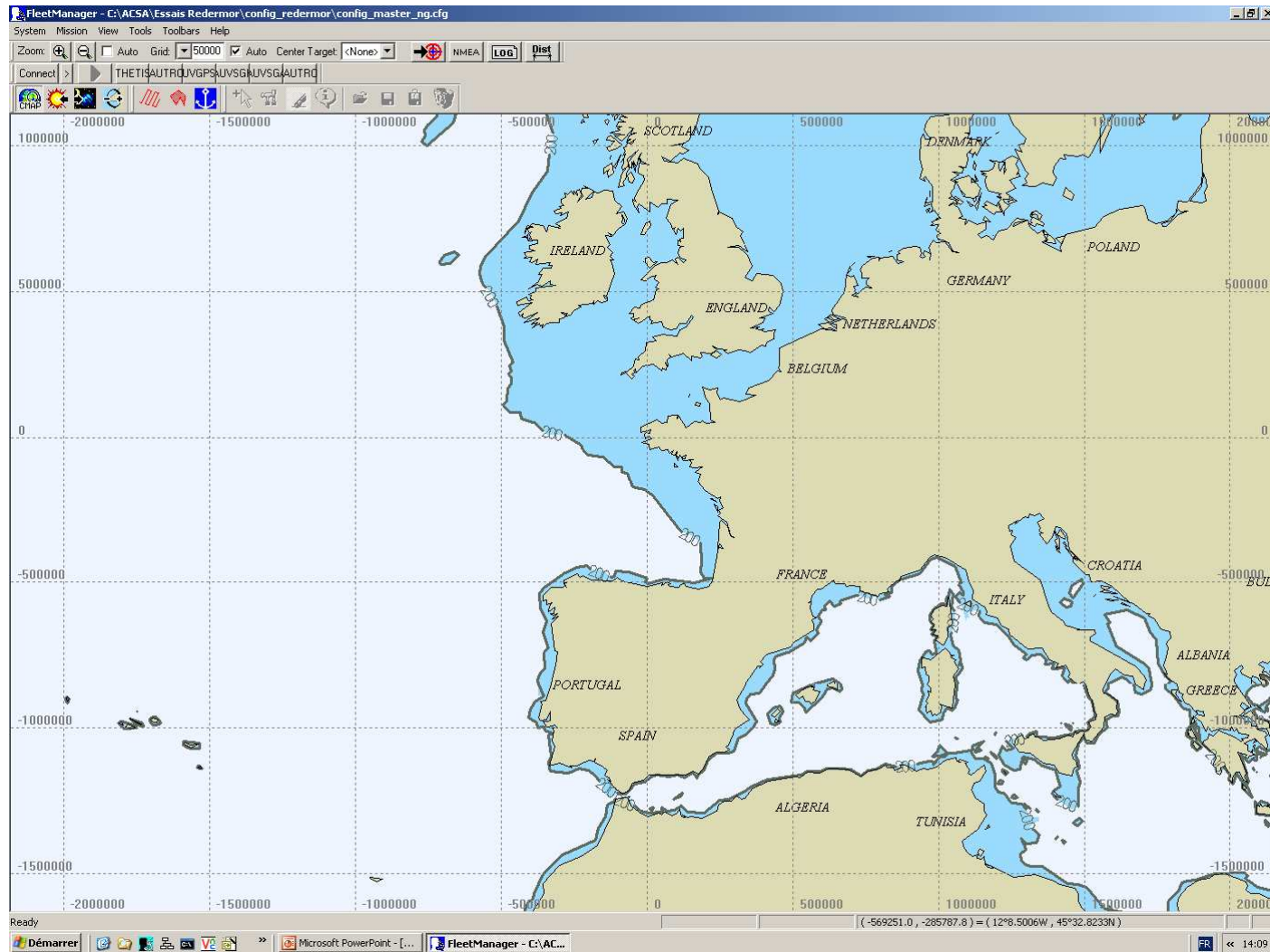
RAZ
IoVehicle : Lancement de l'ecoute des trames d'etat...
IoVehicle::StopCommunication() : Arrêt de l'ecoute des trames d'etat
IoVehicle::ReceiveInitialPosition() :
  Réception de la position initiale réelle du véhicule OK
IoCommandList : Export de la liste de commande (pour simulation) vers "C:/Iovas/MISSIONS/VEH/red...
IoVehicle : Lancement de la simulation externe
IoVehicle : Retour de simulation externe = 0
IoCommandResultLoader : Ouverture d'un fichier de resultat de simulation :
  C:/Iovas/MISSIONS/VEH/redemor/SIMU1/EffetLCdes.txt
IoCommandResultLoader : 728 resultat(s) lu(s)
IoVehicle : Lancement de l'ecoute des trames d'etat...
  
```



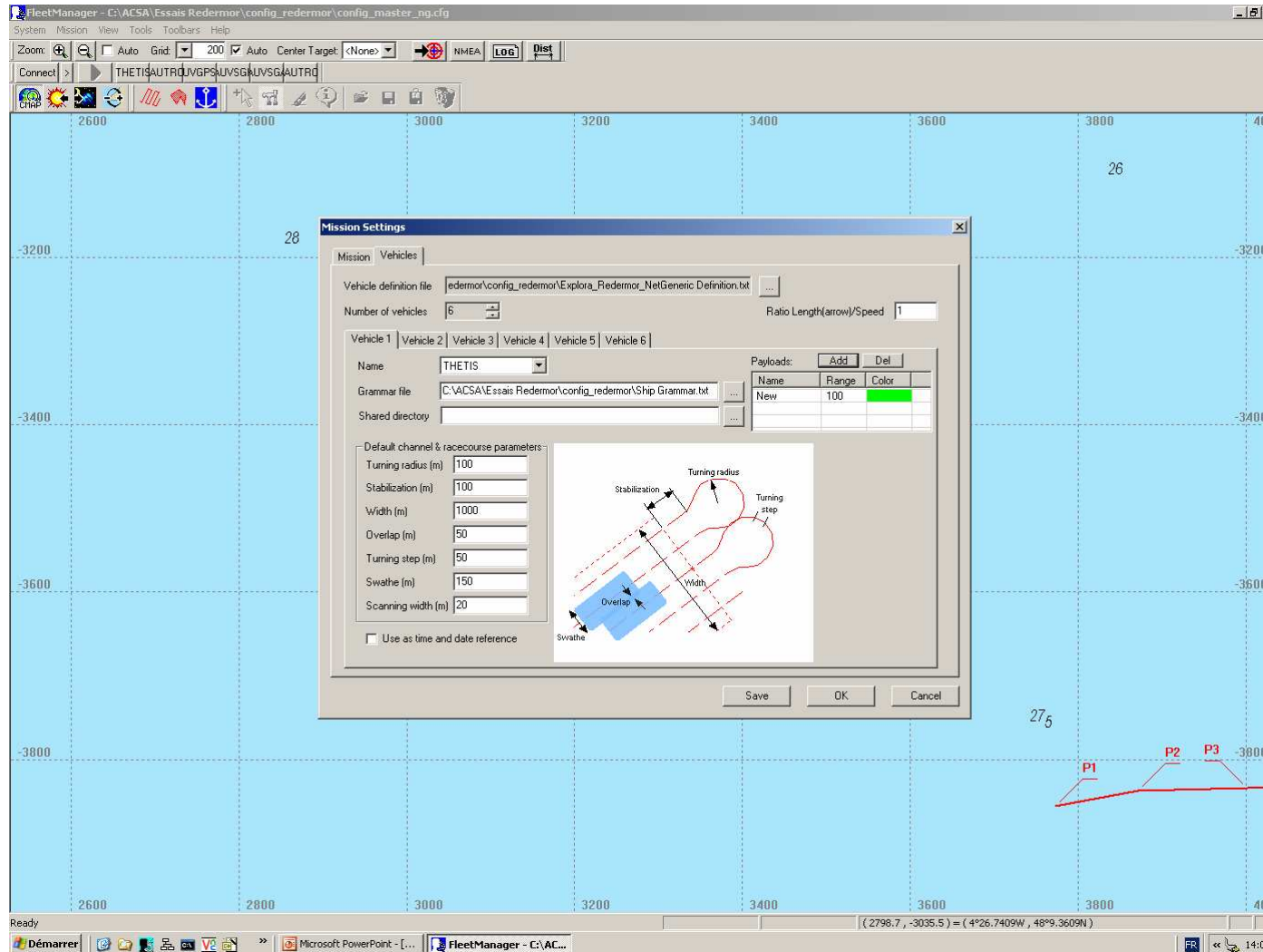




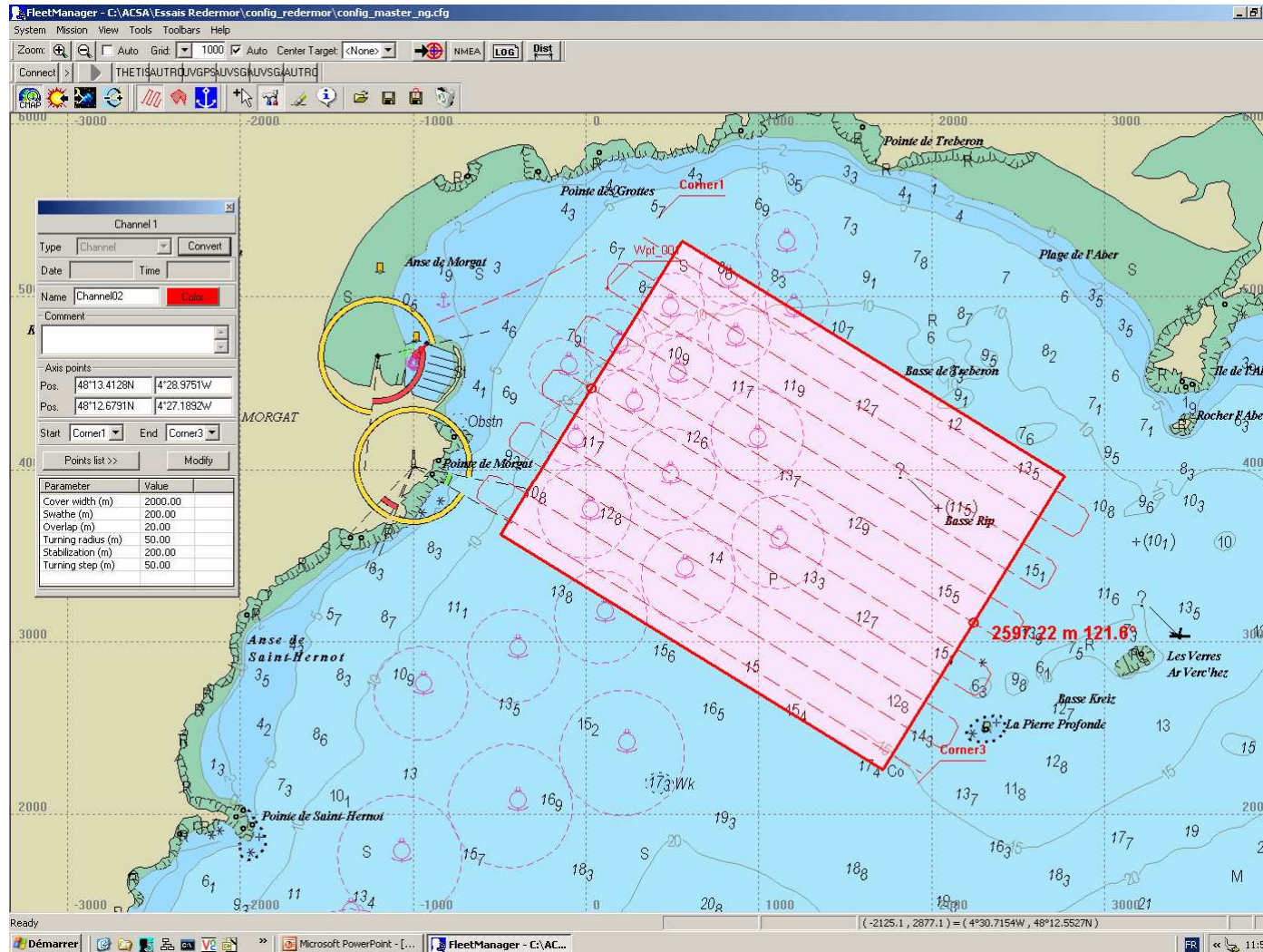
# Level 2 MMI : Fleet manager (ACSA)



# Level 2: what an AUV can do?



# Level 2 : waypoints definition



# Level 2 : mission script

**Mission plan editor for AUVGPSH**

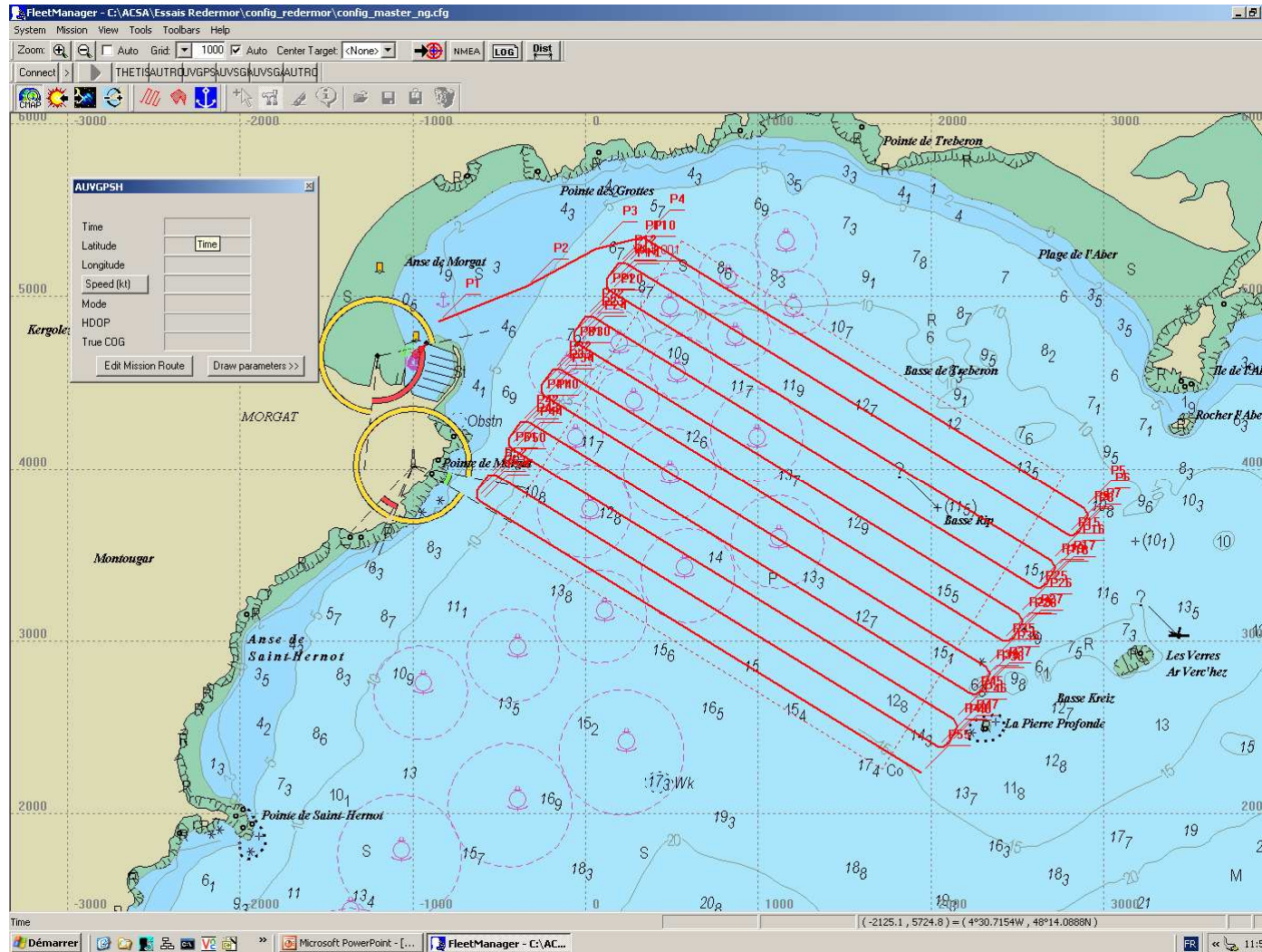
Num.	Route	Point	Command	Latitude	Longitude	mode	Vertical	Consigne V...	Vitesse d'av...
1	Route04	P1	target	048.2269167	-004.49477833	immersion	0.7		2.5
2	Route04	P2	target	048.22885167	-004.48790833	immersion	0.7		2.5
3	Route04	P3	target	048.23079000	-004.48252667	immersion	0.7		2.5
4	Channel02	P1	target	048.23138167	-004.47887000	immersion	0.7		2.5
5	Channel02	P2	target	048.21727000	-004.44452000	immersion	0.7		2.5
6	Channel02	P3	target	048.21689500	-004.44420000	immersion	0.7		2.5
7	Channel02	P4	target	048.21603833	-004.44486167	immersion	0.7		2.5
8	Channel02	P5	target	048.21562500	-004.44542167	immersion	0.7		2.5
9	Channel02	P6	target	048.21581667	-004.44578833	immersion	0.7		2.5
10	Channel02	P7	target	048.23003333	-004.48013833	immersion	0.7		2.5
11	Channel02	P8	target	048.23002500	-004.48078167	immersion	0.7		2.5
12	Channel02	P9	target	048.22924333	-004.48162667	immersion	0.7		2.5
13	Channel02	P10	target	048.22881167	-004.48165000	immersion	0.7		2.5
14	Channel02	P11	target	048.22862500	-004.48140667	immersion	0.7		2.5

**Command keyword**

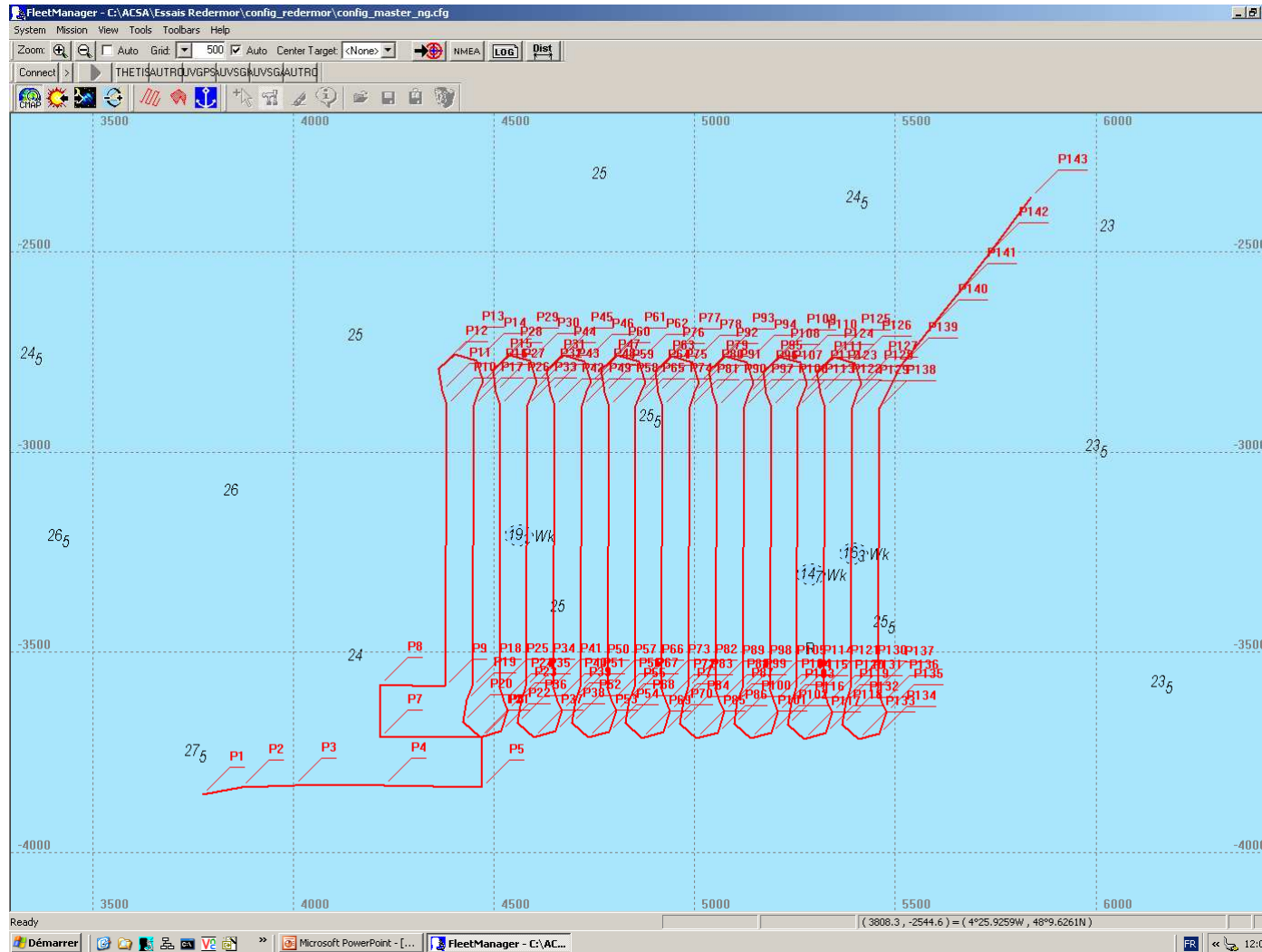
- target
- line\_follow
- circle\_follow
- half\_turn
- rest
- jump\_target
- goto
- entry\_label
- target,048.20586500,-004.45434500,immersion,0.7,2.5,10,0.1,0.3,Doppler // Channel02 - P42
- target,048.20500833,-004.45500833,immersion,0.7,2.5,10,0.1,0.3,Doppler // Channel02 - P44
- target,048.20479333,-004.45556833,immersion,0.7,2.5,10,0.1,0.3,Doppler // Channel02 - P45
- target,048.20486000,-004.45593333,immersion,0.7,2.5,10,0.1,0.3,Doppler // Channel02 - P46
- target,048.21897500,-004.49028500,immersion,0.7,2.5,10,0.1,0.3,Doppler // Channel02 - P47
- target,048.21899667,-004.49092833,immersion,0.7,2.5,10,0.1,0.3,Doppler // Channel02 - P48
- target,048.21821500,-004.49177333,immersion,0.7,2.5,10,0.1,0.3,Doppler // Channel02 - P49
- target,048.21778333,-004.49180667,immersion,0.7,2.5,10,0.1,0.3,Doppler // Channel02 - P50
- target,048.21759667,-004.49155333,immersion,0.7,2.5,10,0.1,0.3,Doppler // Channel02 - P51
- target,048.20348167,-004.45720167,immersion,0.7,2.5,10,0.1,0.3,Doppler // Channel02 - P52



# Level 2: mission supervision



# Level 2 : mission example



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## Level 2 : mission script example

```
Command keyword
target [dropdown] [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 // Channel101 - 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 // Channel101 - 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 // Channel101 - P3
target,048.15819833,-004.42465667,altitude,10.0,2.5,10,0.1,0.3,Doppler // Channel101 - P4
target,048.15852333,-004.42410000,altitude,10.0,2.5,10,0.1,0.3,Doppler // Channel101 - P5
target,048.15838667,-004.42338833,altitude,10.0,2.5,10,0.1,0.3,Doppler // Channel101 - 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)

**I O V A S**  
Interface Opérateur pour Véhicule Autonome Sous-marin



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Office National d'Études et de Recherches Aérospatiales  
CENTRE DE TOULOUSE





# Level 3 : IOVAS MMI

The screenshot displays the IOVAS v2.4b (Niveau 3) mission presentation interface. It features a central map of France with a coordinate grid, a left-hand explorer and properties panel, and a bottom console window.

**Explorateur**

- Io mission\_presentation2
  - environnement
    - Bathymetrie
    - Traits de cotes
    - Courants de marées
    - zones\_interdites\_5
  - vehicules

**redermor**

Charges Utiles	
Vit. Nominale Av. (noeuds)	3.000
Vit. Avance Max (noeuds)	5.000
Rayon Nominal Gir. (m)	50.000
Vit. Giration (deg/s)	1.753
Vit. Giration Max (deg/s)	5.000
Vit. chmt Imm. Max (m/s)	0.100
Vit. chmt Alti-fond Max (m/s)	0.100
Pente immersion nominale (m/100m)	5.000
Alti-fond Min (m)	5.000
Alti-fond Max (m)	300.000

**Etat réel/estimé**

	Durée totale		
	Réel	Estimé	
Temps	0.000	0.000	
Lat	N40 8'13.68	N48 13'39.21	deg
Lon	W10 16'27.63	W 4 39' 8.27	deg
X	-419175.531	-3863.337	m
Y	-910761.688	-11753.580	m
Immersion	0.000	0.000	m
Altitude fond	0.000	0.000	m
Cap	90.000	5.540	deg
Capacité	0.000	0.000	A/h
Vitesse	0.000	1.530	m/s

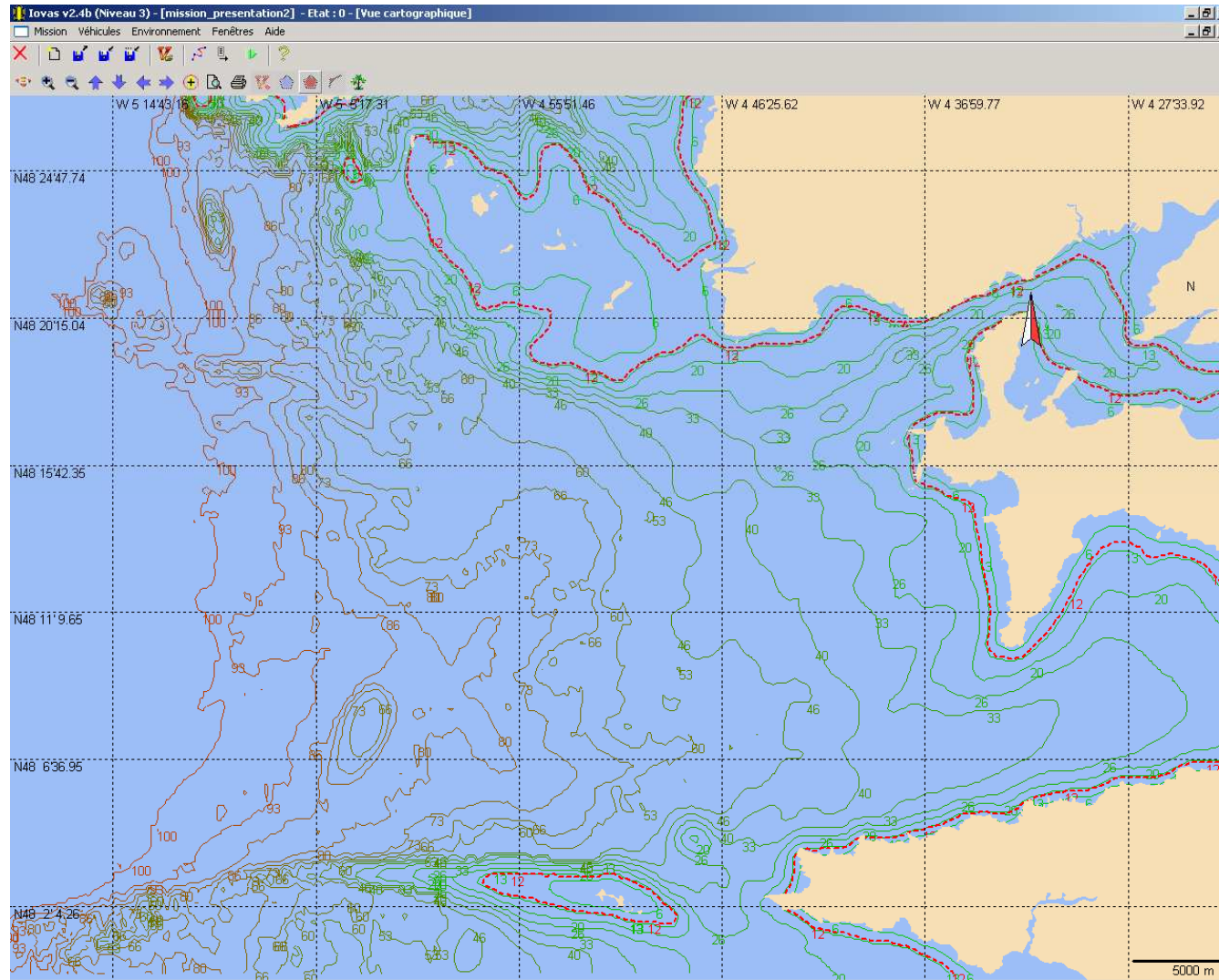
**Console - messages IOVAS**

```

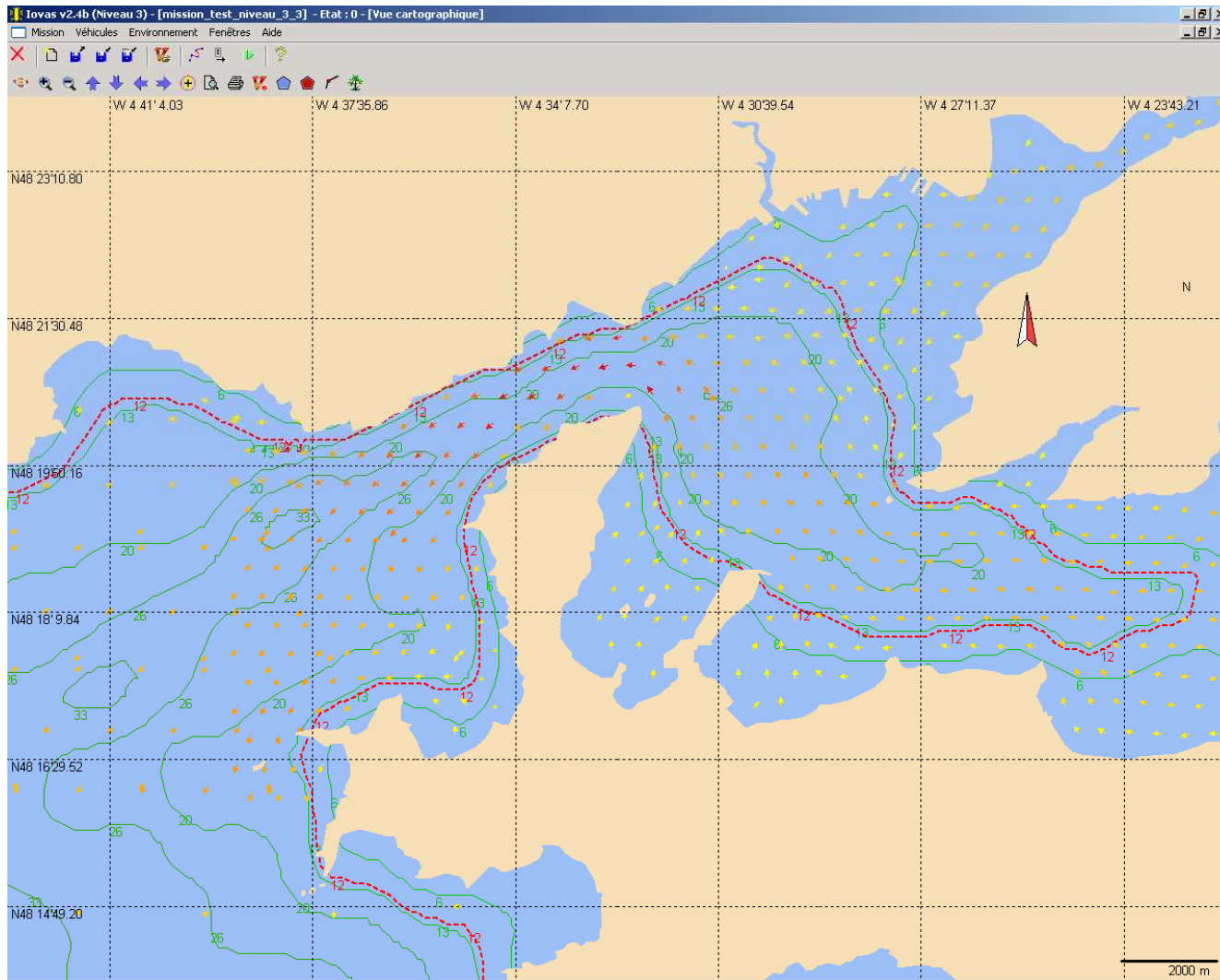
x RAZ
IoMission : Sauvegarde de "C:/Iovas/MISSIONS/MISS3/mission_presentation1.miss3"
IoVehicle:IoVehicle() : Creation d'un véhicule
IoVehicle:LoadScript() : Chargement de "C:/Iovas/MISSIONS/VEH/redermor/proprietes.txt"
IoVehicle3 : Sauvegarde de "C:/Iovas/MISSIONS/VEH/redermor/proprietes.txt"
IoVehicle:IoVehicle() : Creation d'un véhicule
IoVehicle:LoadScript() : Chargement de "C:/Iovas/MISSIONS/VEH/redermor/proprietes.txt"
IoVehicle:IoVehicle() : Fermeture
IoVehicle3 : Sauvegarde de "C:/Iovas/MISSIONS/VEH/redermor/proprietes.txt"
IoVehicle:IoVehicle() : Creation d'un véhicule
IoVehicle:LoadScript() : Chargement de "C:/Iovas/MISSIONS/VEH/redermor/proprietes.txt"
IoVehicle:IoVehicle() : Fermeture
  
```



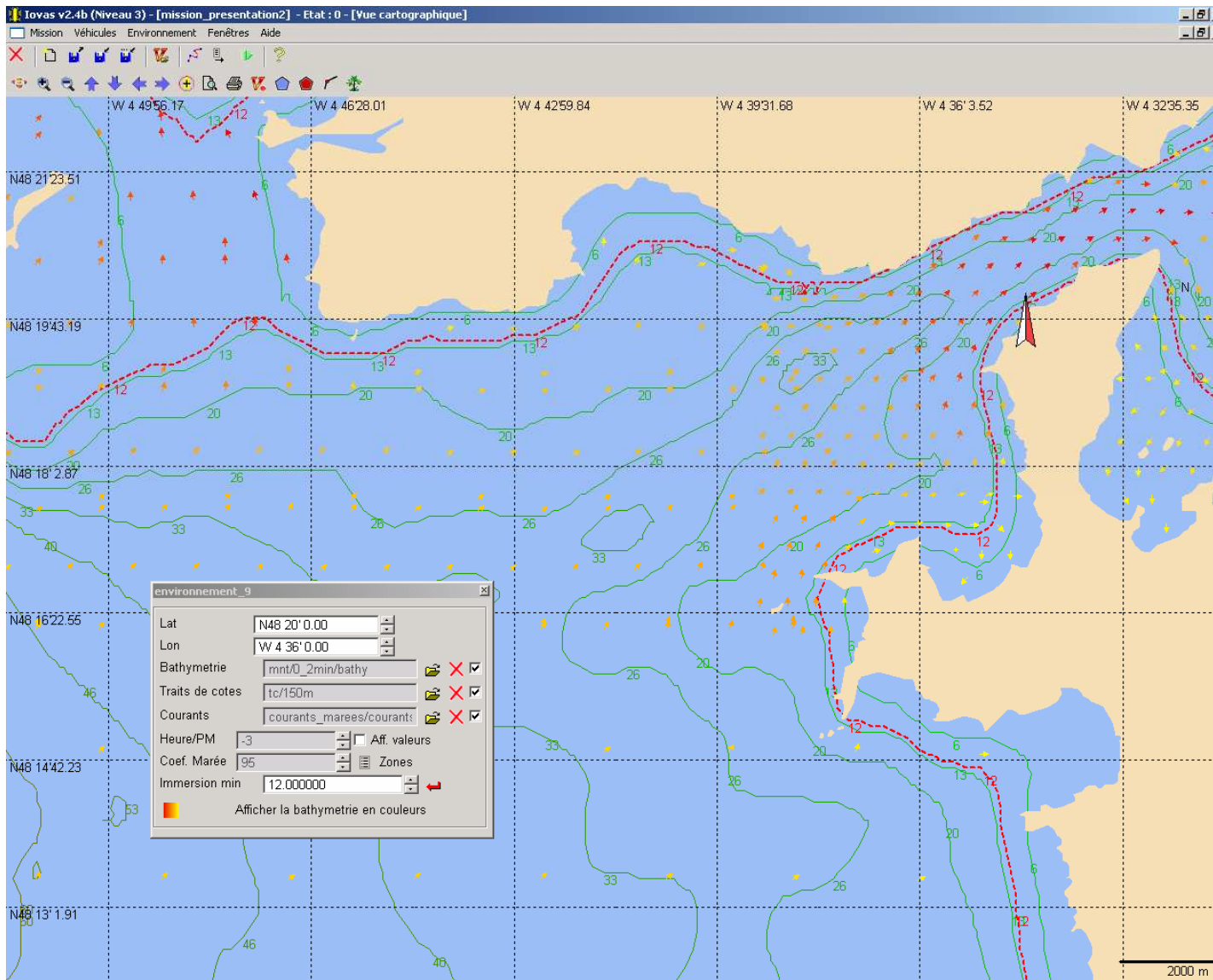
# Level 3 : interaction with environment



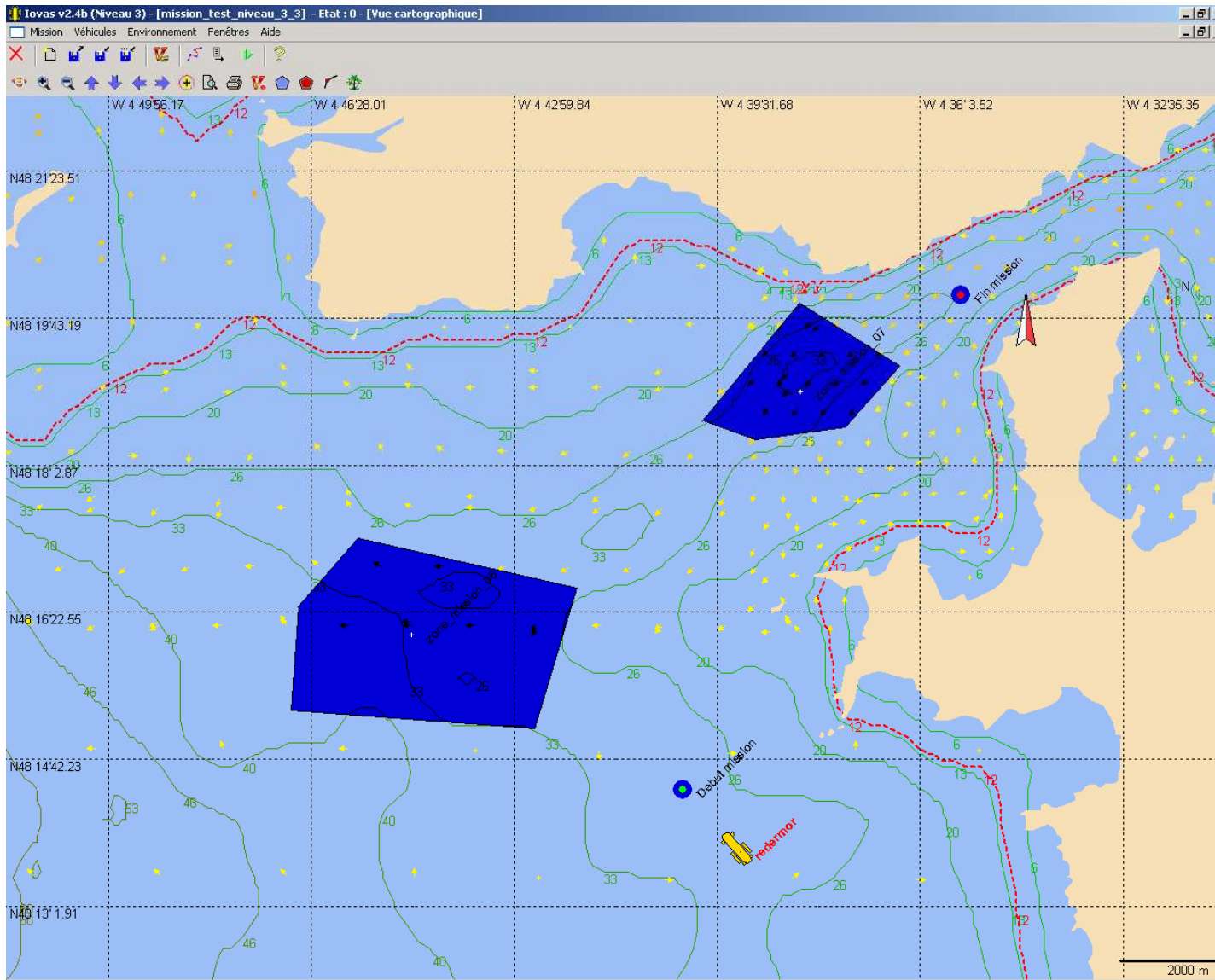
# Level 3 : interaction with environment



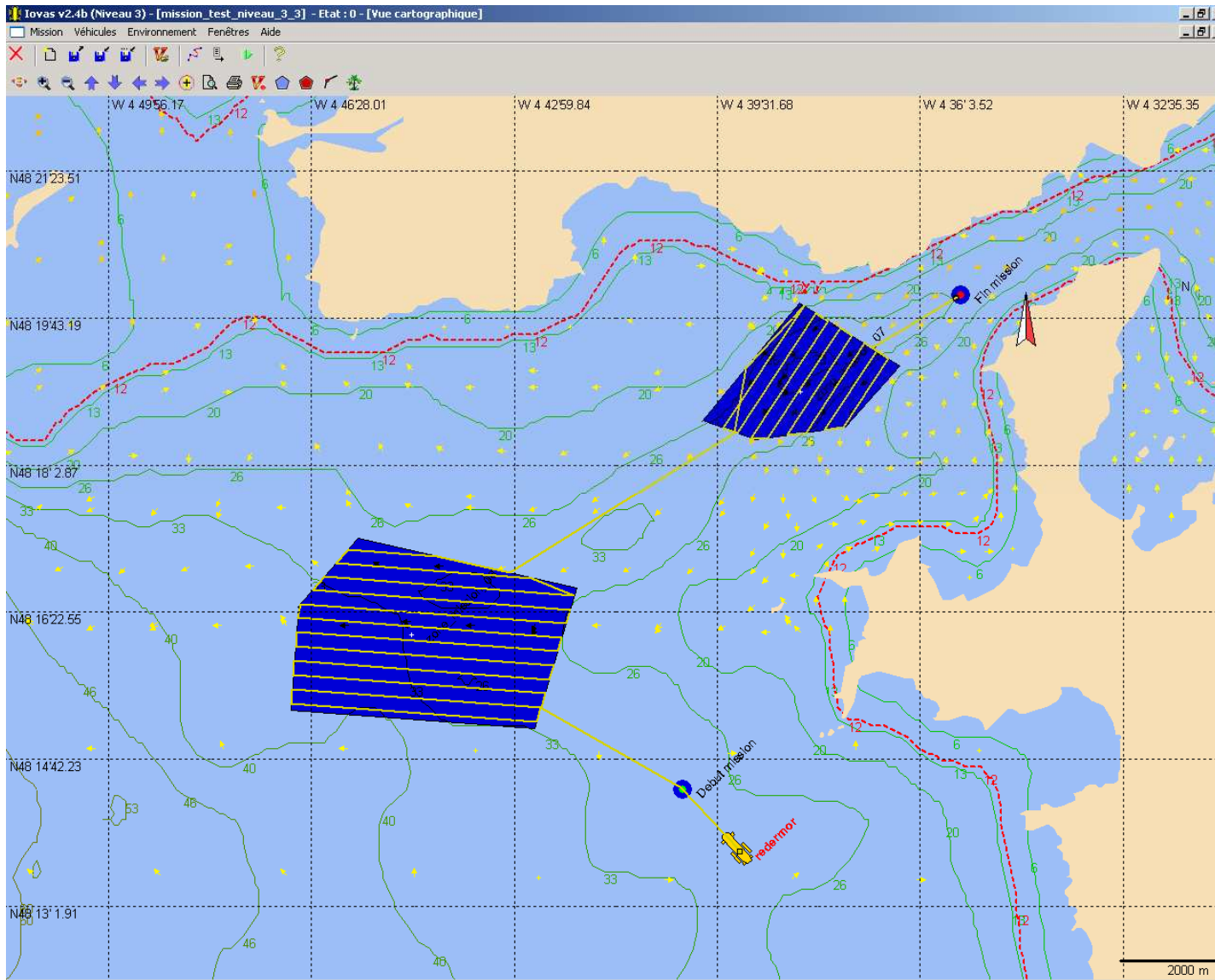
# Level 3 : Mission preparation



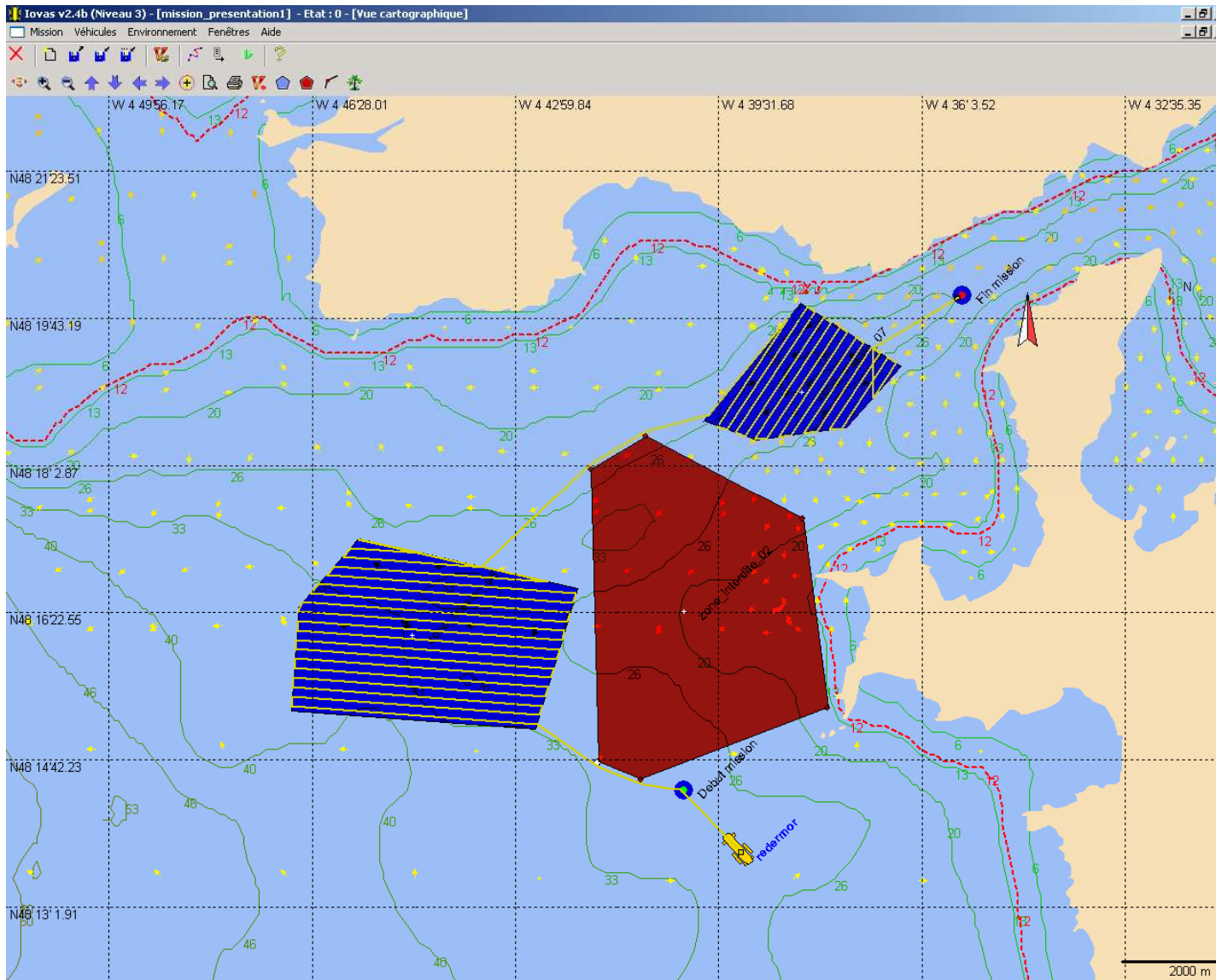
# Level 3: Missions goals



# Level 3: Automatic planning



# Level 3: Automatic planning



# Level 3: mission script?

The screenshot displays a Windows XP desktop environment. A file explorer window is open, showing the directory structure for 'SIMU3' under 'C:\Iovas\MISSIONS\VEH\redermor\SIMU3'. The files listed include 'tmp', 'nouveau\_vehicule\_1' through '5', 'redermor', 'SIMU1', 'SIMU3', 'Bathymetrie.txt', 'Courant.txt', 'Environnement.txt', 'Objectifs.txt', 'param\_idc.txt', 'SCENARIO.txt', 'Vehicule.txt', and 'ZonesNonNav.txt'. Three WordPad windows are open, displaying mission script data:

**SCENARIO.txt - WordPad**

```
repertoire_vehicule C:/Iovas/MISSIONS/VEH/redermor/SIMU3
repertoire_environnement C:/Iovas/MISSIONS/VEH/redermor/SIMU3
repertoire_mission C:/Iovas/MISSIONS/VEH/redermor/SIMU3
repertoire_resultat tmp
```

**Vehicule.txt - WordPad**

```
nom_vehicule redermor
vitesse_avance_nominale_nds 2.000
rayon_giration_nominale_m 40.000
pente_plongee_nominale_m 30.000
positioninitX -24126.666
positioninitY -14798.332
positioninitZ 0.500
positioninitpsi_deg 0.000
vit_chgt_max_mps 0.100
vit_chgt_altfond_mps 0.100
```

**Objectifs.txt - WordPad**

```
nom_zone zone_debut
type_operation DEBUT
isobarycentre -22768.93 -12480.25
charges_utiles 0

nom_zone zone_mission_03
type_operation BALAYAGE
isobarycentre -2179.40 -3654.98
vitesse_av_balay_nds 2.00
alt_fond_balay_m 20.00
la_raies_balay_m 200.00
charges_utiles 0
zone_balay0
-3462.62 -4698.12
-1674.39 -2181.35
-912.73 -2678.08
-2667.85 -5062.39

nom_zone zone_mission_02
type_operation BALAYAGE
isobarycentre -20906.19 -6088.97
vitesse_av_balay_nds 2.00
alt_fond_balay_m 20.00
la_raies_balay_m 200.00
charges_utiles 0
zone_balay1
-22305.32 -7711.63
-23000.74 -5492.89
-19656.08 -4300.73
-18662.62 -6850.62

nom_zone zone_mission_01
type_operation BALAYAGE
isobarycentre -13099.22 -7272.85
vitesse_av_balay_nds 2.00
alt_fond_balay_m 20.00
la_raies_balay_m 200.00
charges_utiles 0
zone_balay2
-17371.11 -7016.20
-11112.29 -3737.77
-8827.33 -7645.39
-15086.15 -10692.02

nom_zone zone_fin
type_operation FIN
isobarycentre -4721.01 -2777.42
```





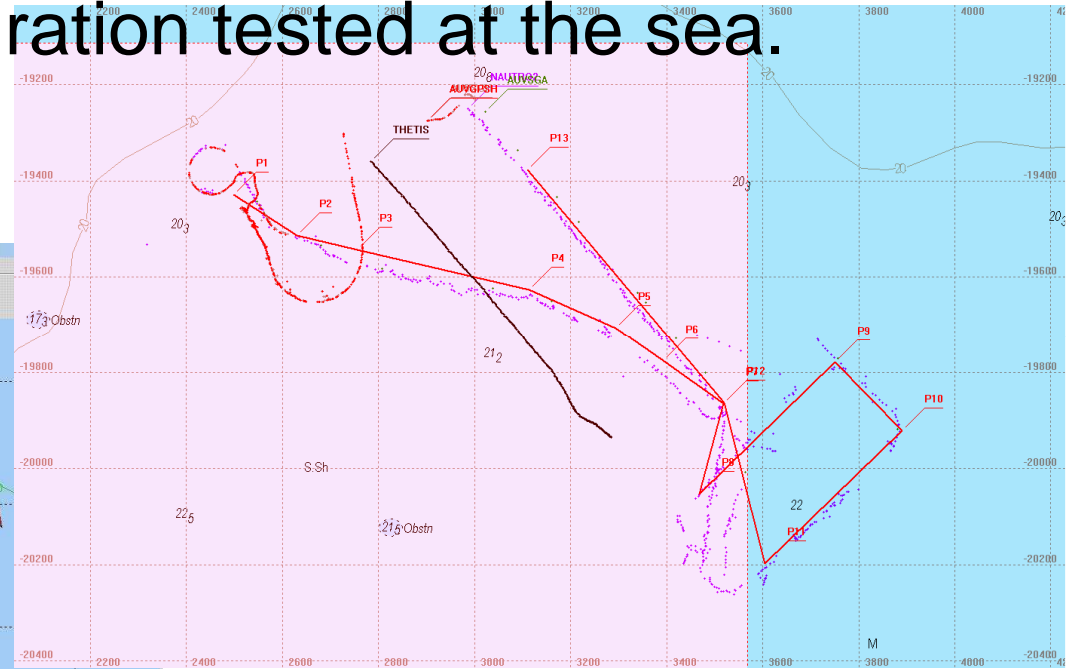
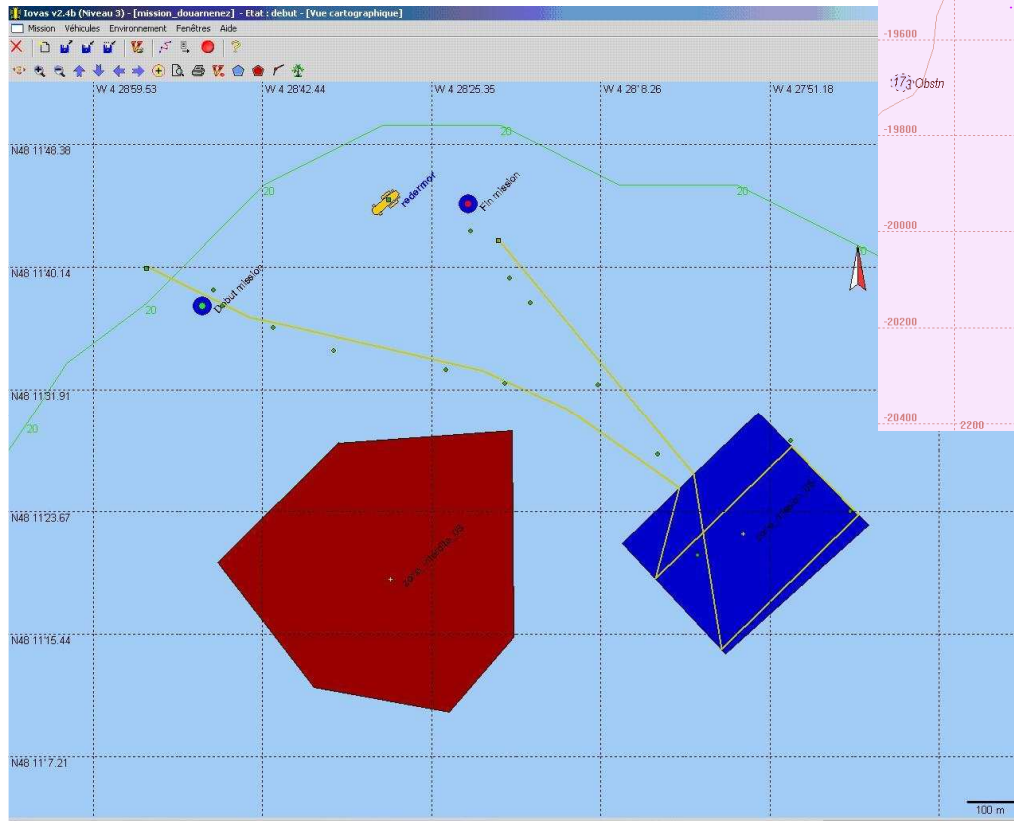
# On-going test

- 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...