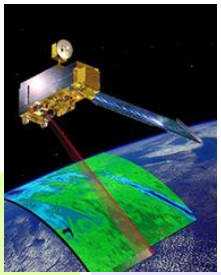
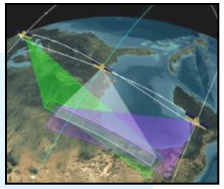
AIS: Technology Development to Commercialization

NSAW – 2010





Dr. Elliott Coleshill

Mission Development Group

COM DEV Ltd

Outline

COMDEV / MDG Overview
The AIS Problem
The Trials
    Simulations,
    Harbour/Aircraft
    Quick AIS
    NTS – The Nano-satellite that Could
Spinoff into Commercial Industry (exactEarth)
Current Mission Designs
    HIP-1
    ADS-1B
    M3MSAT
Summary

COM DEV / MISSION DEVELOPMENT GROUP

COM DEV at a Glance

- **In operation since**: 1974
- **2009 Revenues**: $240M
- **Size**: 1377 + employees – 5 facilities
- **Patents**: 200 granted or pending
- **Public Ownership**: TSX-CDV
- **Satellite Contracts to date**: 700+

Cambridge, ON

Aylesbury, UK

Ottawa, ON

El Segundo, CA

MDG-Cambridge, ON

Most prolific supplier of payload equipment for commercial communication satellites

LOCKHEED MARTIN
Since 1975

MDA

ThalesAlenia Space
A Thales / Finmeccanica Company
Since 1982

EMS Technologies
Since 1982

SURREY SATELLITE TECHNOLOGY LTD
Since 2004

Telesat

Orbital
Since 1995

CSA ASC
Since 1987

CAST
CASC
Since 1995

इसरो isro
Since 1997

BOEING
Since 1979

SPACE SYSTEMS LORAL
Since 1975

EADS astrium
Since 1982

NORTHROP GRUMMAN
Space Technology
Since 1987

NEC/TOSHIBA
Since 1990

MITSUBISHI ELECTRIC
Since 1990

esa
Since 1984

Relationships with all satellite primes – lasting decades.

COM DEV On Board

ACE
ACES - GARUDA-1
ACTS
ADEOS-1
ADEOS-2
AEHF
AFRISTAR
AMAZONAS
AMAZONAS 2
AMC-1
AMC-10
AMC-11
AMC-12
AMC-14
AMC-15
AMC-16
AMC-18
AMC-2
AMC-21
AMC-23
AMC-3
AMC-4
AMC-5
AMC-5R
AMC-6
AMC-7
AMC-8
AMC-9
AMOS 2
AMOS 3
ANIK F1R
ANIK F2
ANIK F3
ANIK-B
ANIK-C
ANIK-D
ANIK-E
ANIK-F1
APSTAR 6
APSTAR II R
AQUA
ARABSAT
ARABSAT 2
ARABSAT 3A
ARABSAT 4A
ARABSAT 4AR
ARABSAT 4B
ARABSAT 5A
ARABSAT 5B
ARTEMIS
ASCAT/METOP
ASIASAT 5
ASIASAT-2
ASIASAT-4
ASIASTAR
ASTRA 1A
ASTRA 1B
ASTRA 1C
ASTRA 1D
ASTRA 1K
ASTRA 1KR
ASTRA 1L
ASTRA 1M
ASTRA 2B
ASTRA 3B
ASTROLINK
ATLANTIC BIRD 1
ATLANTIC BIRD 2
AURORA II
AUSSAT
AUSSAT-B
BOLIVARSAT MK II
BRAZIL 1
BRAZILSAT
BS3N
BSAT
BSAT 2B
BSAT 2C
BSAT 3A
CAKRAWARTA
CARTOSAT-1
CASSINI
CHINASAT 6B
CHINASAT 9
CIELSAT 2
CLOUDSAT
CMBSTAR
COLUMBUS
CONTOUR
COSMO/SKYMED
CPA (FREJA)
CRYOSAT
CS-2
CTS
DAWN
DBS/COMSAT
DIRECTV 10
DIRECTV 10R
DIRECTV 11
DIRECTV-5
DIRECTV-7S
DIRECTV-8
DIRECTV-9S
DRTS
DSCS III A3
DSCS III B6
E-BIRD
ECHOSTAR 14
ECHOSTAR I
ECHOSTAR II
ECHOSTAR III
ECHOSTAR IV
ECHOSTAR IX
ECHOSTAR V
ECHOSTAR VI
ECHOSTAR VII
ECHOSTAR VIII
ECHOSTAR X
ECHOSTAR XI
EKPRESS MD-1
EKPRESS MD-2
EKSPRESS 33
EKSPRESS 44
EKSPRESS AM-1
EKSPRESS AM-22
ENVISAT
ERS-1/2
EURASIASAT 1
EUROBIRD
EUTELSAT W1
EUTELSAT W2
EUTELSAT W2A
EUTELSAT W2M
EUTELSAT W3
EUTELSAT W3A
EUTELSAT W4
EUTELSAT W5
EUTELSAT W7
EXPRESS AM-2
EXPRESS AM-3
FUSE (FES)
GALAXY 10R
GALAXY 12
GALAXY 13
GALAXY 14
GALAXY 15
GALAXY 16
GALAXY 17
GALAXY 18
GALAXY 25
GALAXY 26
GALAXY 27
GALAXY 28
GALAXY 3C
GALAXY 4
GALAXY 4R
GALILEO IOV
GALS R16
GENESIS-1
GIOVE-2A
GIOVE-A
GLOBALSTAR
GOES N
GOES O
GSAT-6
GSAT-2
GSAT-3
G-STAR
HAI YANG
HELLASAT
HIMAWARI
HISPASAT
HISPASAT 1C
HISPASAT 1D
HORIZONS-2
HOTBIRD 10
HOTBIRD 4
HOTBIRD 5
HOTBIRD 6
HOTBIRD 7
HOTBIRD 8
HOTBIRD 9
HOTBIRD FM3
HTSSE-11 (ARGOS)
HYLAS
ICO
ICO F1
ICO F2
IMAGE
INMARSAT 2
INMARSAT 3
INMARSAT 4
INSAT 2
INSAT 2E
INSAT 3A
INSAT 3B
INSAT 3C
INSAT 3E
INSAT 4A
INSAT 4B
INSAT 4C
INSAT 4CR
INSAT 4D
INTELSAT 10
INTELSAT 11
INTELSAT 12
INTELSAT 14
INTELSAT 15
INTELSAT 1R
INTELSAT 5
INTELSAT 6B
INTELSAT 7
INTELSAT 701
INTELSAT 702
INTELSAT 703
INTELSAT 704
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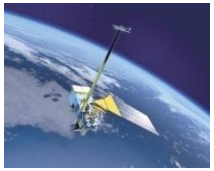
INTELSAT 8
INTELSAT 801
INTELSAT 802
INTELSAT 803
INTELSAT 804
INTELSAT 9
INTELSAT 901
INTELSAT 902
INTELSAT 903
INTELSAT 904
INTELSAT 905
INTELSAT 906
INTELSAT 907
IA-9
INTELSAT V
INTELSAT VA
INTELSAT VI
INTELSAT-K
IRIDIUM
ITALSAT
JASON 1 SS
JCSAT 11
JCSAT 11R
JCSAT 8
JCSAT 9
JCSAT-3A
JCSAT-4A
KAKEHASHI
KAZSAT-1
KOREASAT
LMI-1
LOCSTAR
LOUTCH 5A
LOUTCH 5B
M2
MABUHAYSAT
MARS 2001
MARS 98 - STARDUST
MARS EXPLORER
MARS OBSERVER
MARSCHALS
MBSAT
MCI
MEASAT
MEASAT 3
MEASAT 4
MIMR
MIPAS
MORELOS
MORELOS III
MSAT-1
MSG-1
MSG-2
MSG-3
MSG-4
MSV
MT-SAT
MTSAT 2
MUGUNGWHA-2
MUGUNGWHA-3
MUGUNGWHA-5
MUOS 1
MUOS 2
NAHUEL 1A
NEAR
NIGCOMSAT
NILESAT
NILESAT 102
NIMIQ
NIMIQ 3
NIMIQ 4
NIMIQ 5
NIMIQ-2
NSS 6
NSS 7
NSS 8
NSS-12
NSS-9
NSTAR
NSTAR C
OLYMPUS
OPTUS 1C
OPTUS D1
OPTUS D2
OPTUS D3
ORION 1
ORION 3
PALAPA
PALAPA-C
PALAPA-D
PAN
PANAMSAT
PANAMSAT 11R
PANAMSAT 4R
PROTOSTAR 1
PROTOSTAR 2
RADARSAT
RAINBOW
RASCOM
SATCOM
SATCOM BW
SATCOM C3
SATCOM C4
SATCOM F4/F5
SATCOM K1/K2/K3/K4
SATMEX 6
SBIRS
SCISAT
SCS-1
SCS-1 REPLACEMENT
SES-1
SESAT
SE-SAT
SICRAL 1A
SICRAL 1B
SINOSAT 2A
SINOSAT-3
SIRIUS 1 (CD-RADIO)
SIRIUS 2
SIRIUS 2 (CD-RADIO)
SIRIUS 3 (CD-RADIO)
SIRIUS 4
SIRIUS 5
SIRIUS 6
SKYNET 5A
SKYNET 5B
SKYNET 5C
SKYNET 5D
SMS (AKEBONO)
SOLIDARIDAD
SPACENET
SPACEWAY-1
SPACEWAY-2
SPACEWAY-3
SPAINSAT
SPOT 4
ST-1
STAR 1C
STAR 2C
STARDUST
STELLAT
STELLAT-5
STENTOR
SUPERBIRD 4
SUPERBIRD 5
SUPERBIRD 5
SUPERBIRD 6
SUPERBIRD 7A
SUPERBIRD 7B
SUPERBIRD A
SUPERBIRD B
SUPERBIRD B-R
SUPERBIRD C
SYRACUSE 3A
SYRACUSE 3B
T1
TDRS-I
TDRS-J
TDRSS
TDRSS-7
TELECOM II
TELKOM 1
TELKOM 2
TELSTAR
TELSTAR 11N
TELSTAR 14
TELSTAR 4 FM1
TELSTAR 4 FM2
TELSTAR 4 FM3
TELSTAR 5
TERRA
TERRASTAR
THAICOM
THAICOM 5
THAICOM3
THOR II
THOR IIR
THURAYA-1
THURAYA-2
TIMED
TOPSAT
TPA (NOZOMI)
TURKSAT 3A
UARS
UK DBS
VIKING
VINASAT
WESTAR
WGS-1
WGS-2
WGS-3
WORLDSTAR
XINNUO-1
XM-3
XM-5
XM-RADIO
XM-ROCK
XTAR
YAHSAT 1
YAHSAT 2
YAMAL (2)
YAMAL 201
YAMAL 202
YAMAL 300
ZHONG WEI
ZHONGXIN
ZI YUAN
ZI YUAN 2B

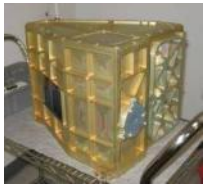
COM DEV is the world's most prolific supplier of satellite equipment - with products and sub-systems on more than 700 satellites and counting.

COM DEV

Wide Range of Challenging Activities

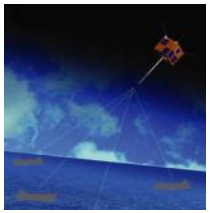
SEARCH AND RESCUE
transponder payloads *for* satellite-based beacon tracking





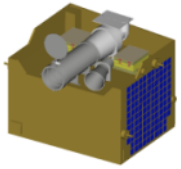
ASTRONOMICAL IMAGERS
large aperture, low-distortion systems for imaging the universe from UV to FIR

ISR FROM SPACE
automatic identification system for global mapping of shipping traffic



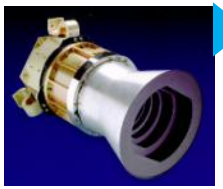
ATMOSPHERIC REMOTE SENSING
sensitive pollution mapping, atmospheric composition and dynamics, weather and climate monitoring

SPACE SITUATIONAL AWARENESS
high accuracy, high sensitivity monitoring of space resident objects.



SPACE ENVIRONMENT
in-situ plasma composition and dynamics analysis for space weather monitoring

SPACE EXPLORATION
custom instruments for robotic and manned exploration



FINE GUIDANCE SENSORS
accurate, autonomous real-time attitude transducers allowing spacecraft to navigate by the stars

Mission Development Group

- Officially stood up in 2008
- Mandate is to provide space-based mission solutions to a variety of problems using microsatellites.
- AIS is the first problem that was addressed.
- Focus is on ‘microspace’ approach: Quick response, dedicated team with wide skill sets, may use COTS parts, subcontractors and subject matter experts as required.
  - “micro” space is at the other end of “big” space
- Microspace philosophy is a way to get to orbit at lower cost and take smarter risks.

Video

SPACE BASED AIS

WHAT IS AIS?

Terrestrial AIS

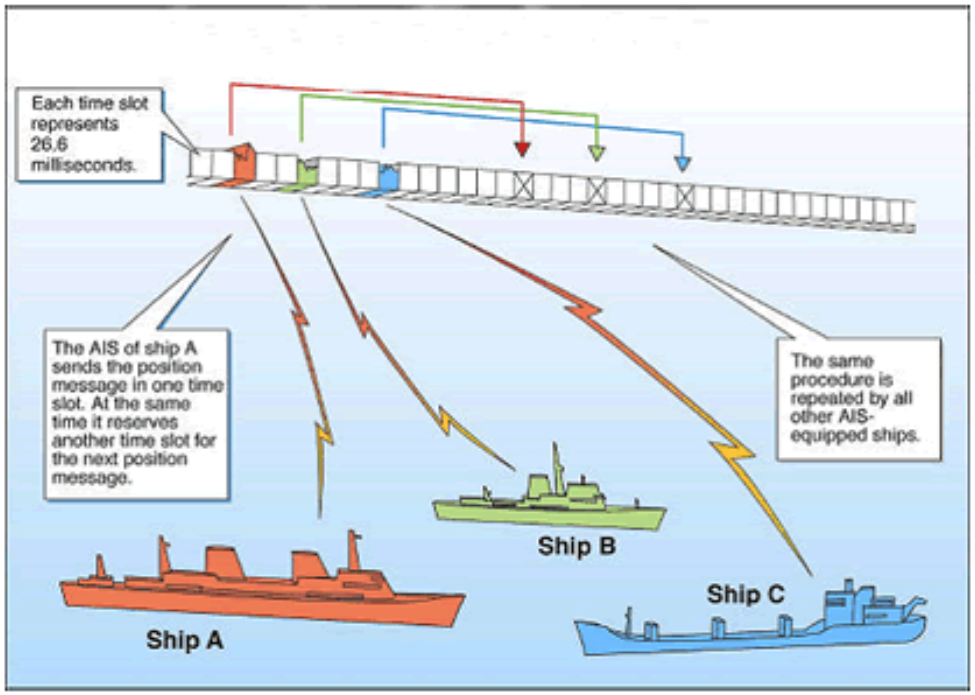
• Automatic Identification System (AIS) as specified by IMO, is a ship and shore based broadcast system, operating in the VHF maritime band.

• AIS is capable of sending and receiving ship information such as identity, position, course, speed, ship particulars and cargo information to and from other ships and shore stations

• It can handle over 4,000 reports per minute and updates information as often as every two seconds.

• AIS uses Self-Organising Time Division Multiple Access (SOTDMA) technology. "Cells"

• Shipboard AIS provides automatic and accurate information regarding risk of collision by calculating Closest Point of Approach (CPA) and Time to Closest Point of Approach (TCPA)

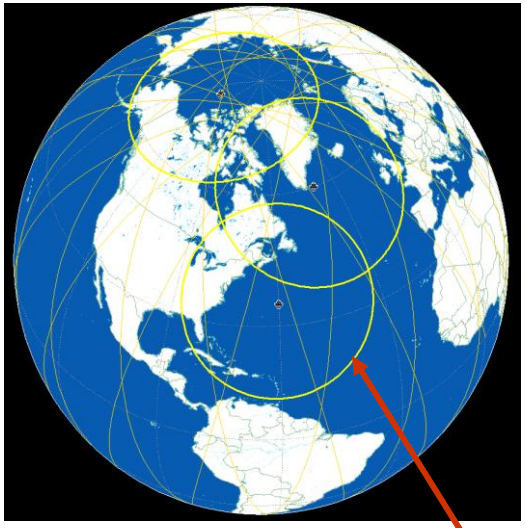


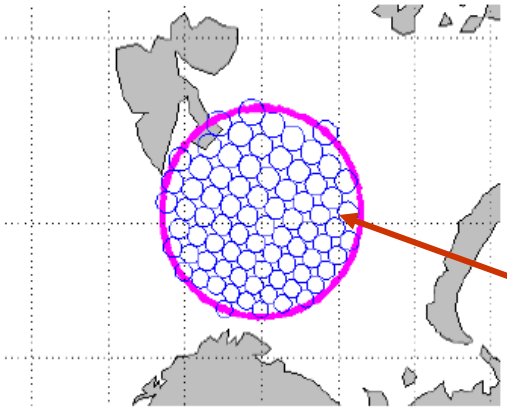
Terrestrial, Line-of-sight system, Self Organized within Cells ~40 nm.

Not designed for reception from space

AIS From Space

- Some important technical questions need to be addressed:
  - AIS signal strength from space
    - Ships pitch/roll and use dipole antennas with deep overhead null
    - Gain/Size of antenna on satellite [vs. size of satellite]
  - Field of view from space
    - Many cells in view simultaneously
    - Signal 'Collisions'
    - Can signals be decoded?
    - What is probability of detection?

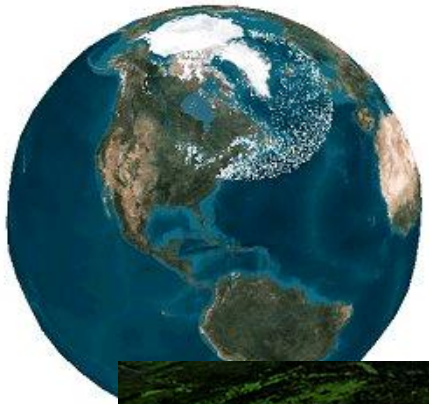




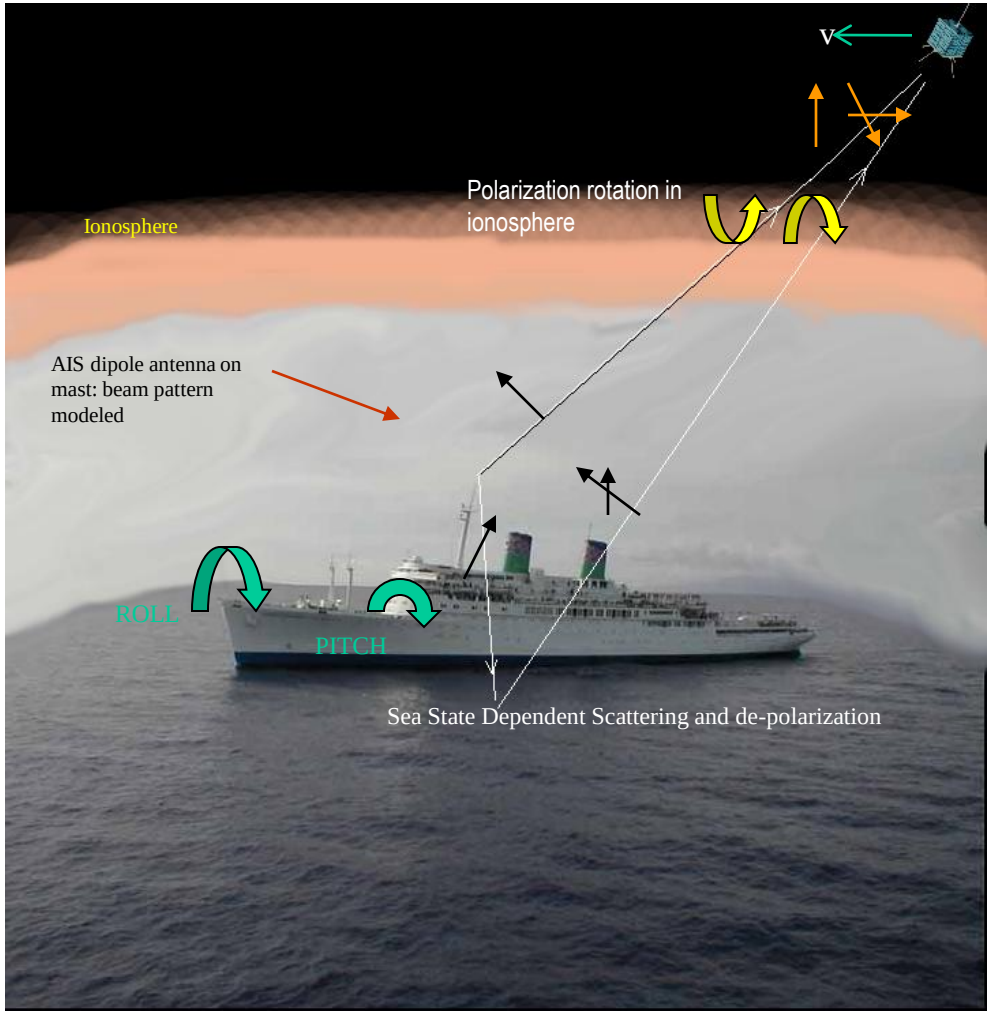
THE TRIALS

Path to AIS Feasibility

- Extensive, high-fidelity simulations (2005)
- Harbor testing in Vancouver & Halifax (2006)
- Aircraft AIS trials at 29,000 ft. (2007)
- NTS AIS nano-satellite launch (2008)



AIS Simulator: Signal Propagation Models



Satellite ephemeris, Doppler shift, receive antenna gain, receiver noise accounted.

Faraday rotation in ionosphere dependent on day/night.

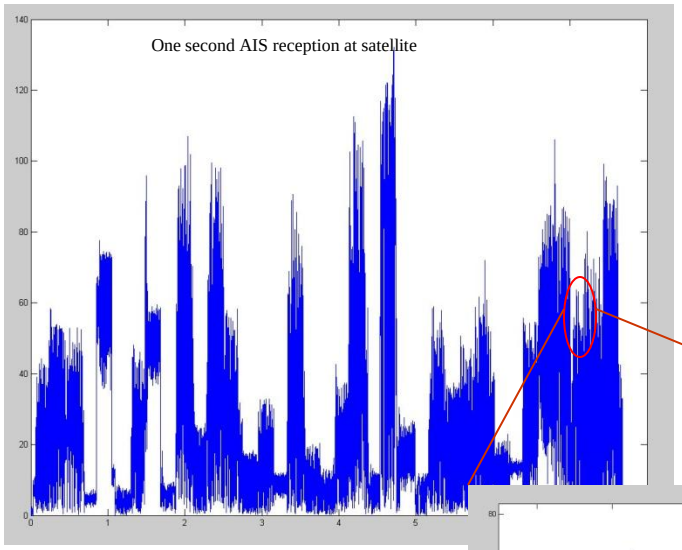
Reflection & De-polarization due to Sea State

Pitch and roll of the ship varies gain to satellite and sea surface.

Simulator generates AIS signals at the satellite that can be sent to a decoding processor and collision statistics calculator

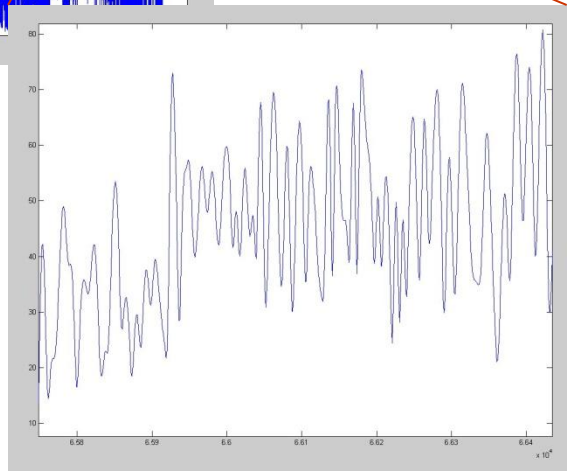
Simulator Output

Satellite near pole
Little traffic in FOV

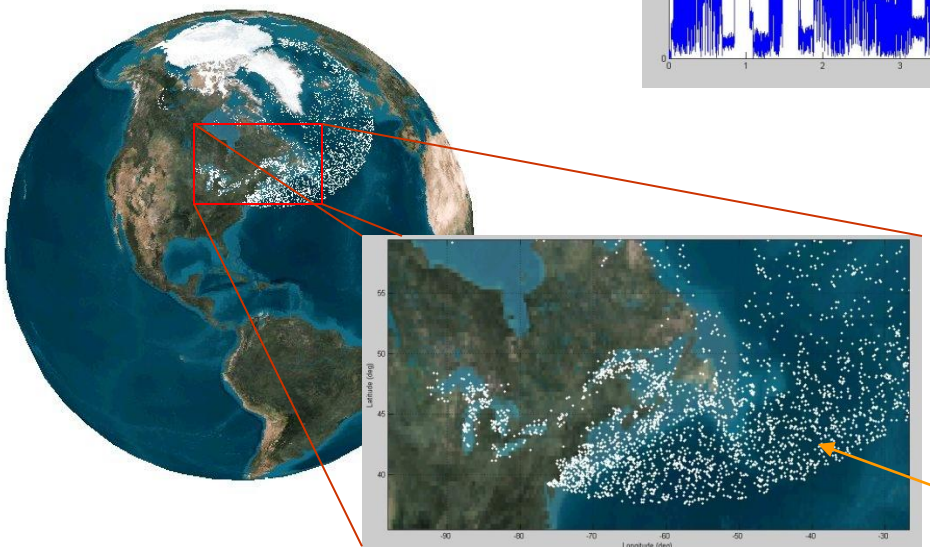


GMSK AIS signals received at satellite, demodulated to baseband. Collisions are apparent.

zoom



Satellite near southern tip of Greenland



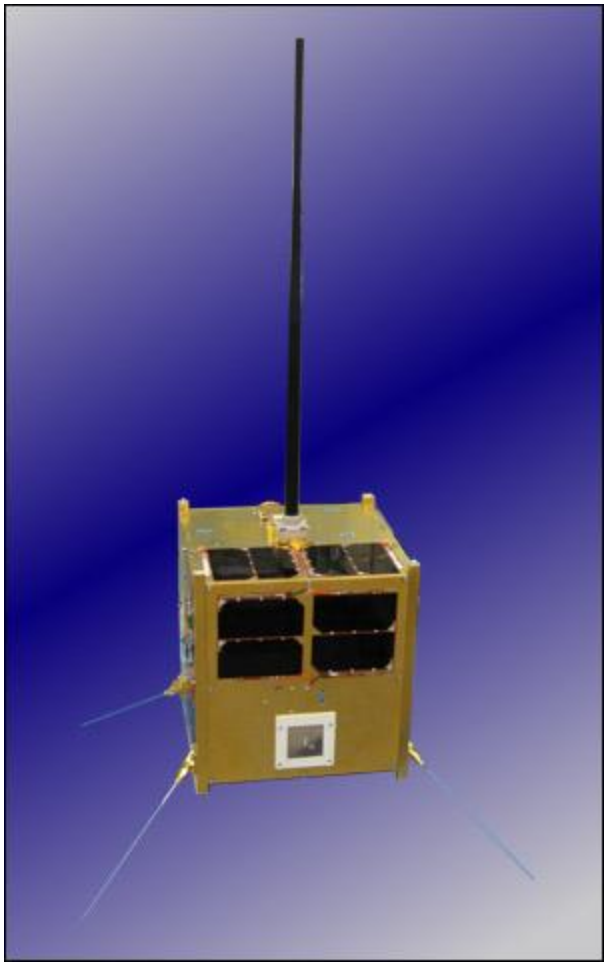
Moving ship traffic

NTS Characteristics

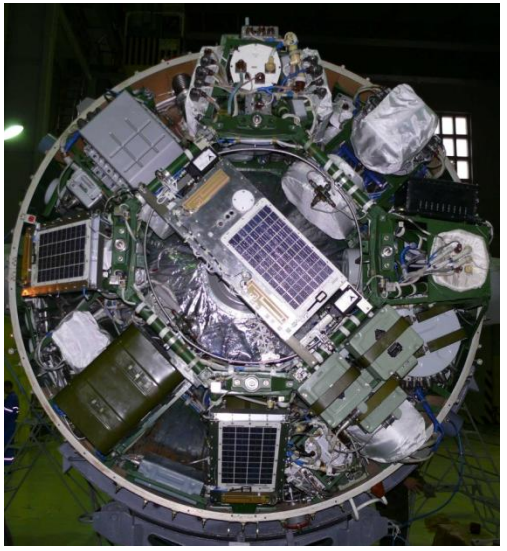
- ❑ Limited AIS data storage capacity (90 seconds of sampled baseband data, both AIS channels)
- ❑ Limited AIS data downlink capacity (32 kbps)
- ❑ Field of view: 5200 km diameter. (Altitude: 630 km)
- ❑ Attitude control: magnetically damped. Antenna gain null points Nadir near the poles.

CONCEPT OF OPERATION:

Demonstration satellite only! Proof of concept for detection algorithms. Take 90 seconds of AIS observation, and then download this over the slow downlink over a period of about 3-4 days!

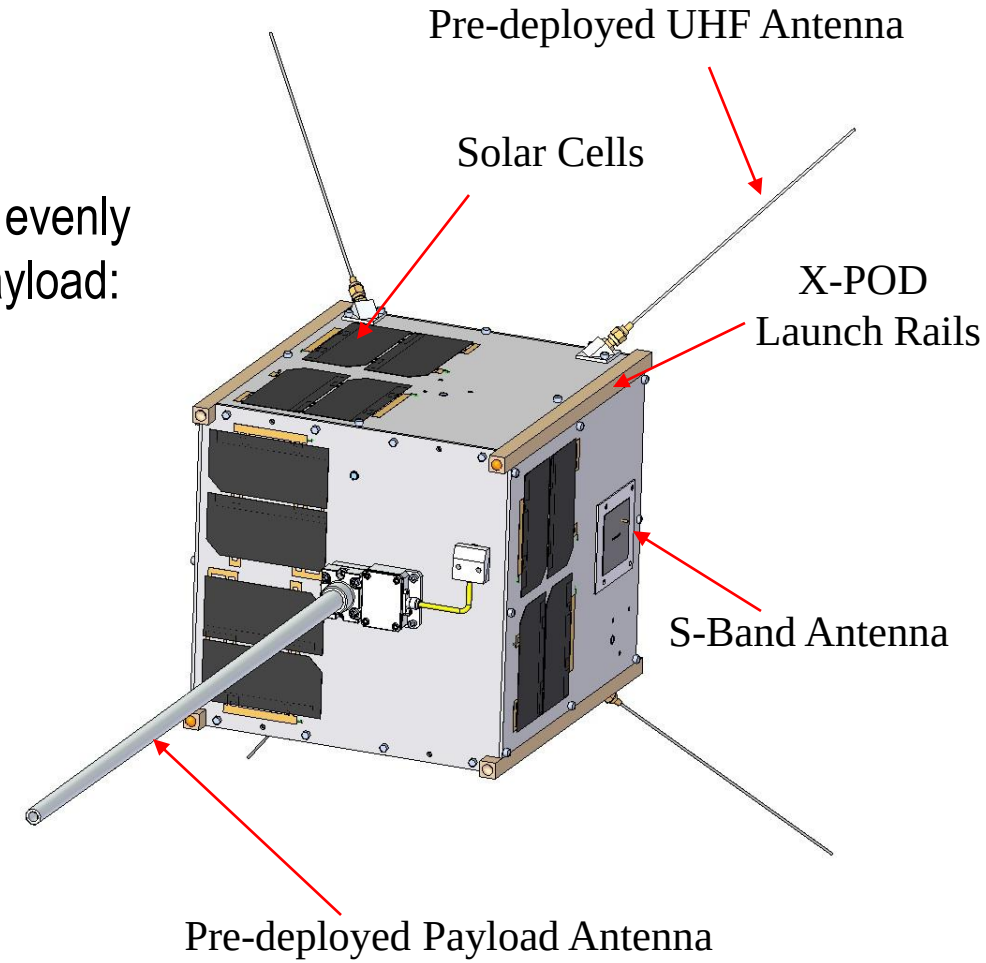


14 messages/s global average detection rate



Introduction to the NTS Spacecraft

- Envelope: 20 x 20 x 20 cm cube
- Mass: 6.5 kg
- Power provided by 24 cells distributed evenly on all sides. Available power for the payload:
  - Peak: 8 Watts
  - Orbit Average: 0.75 Watts
- Payload and communication antennas launched in deployed state
- Communications
  - Uplink: 4 kbps at UHF
  - Downlink: 32 kbps at S-Band
  - 4 whip antennas

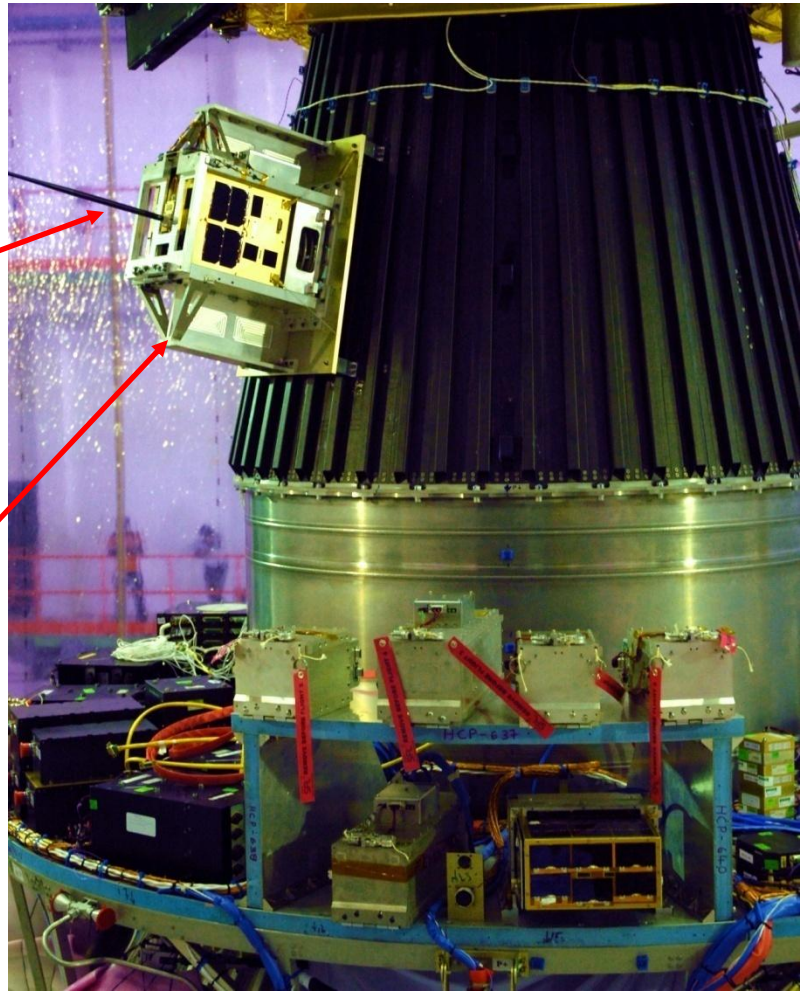


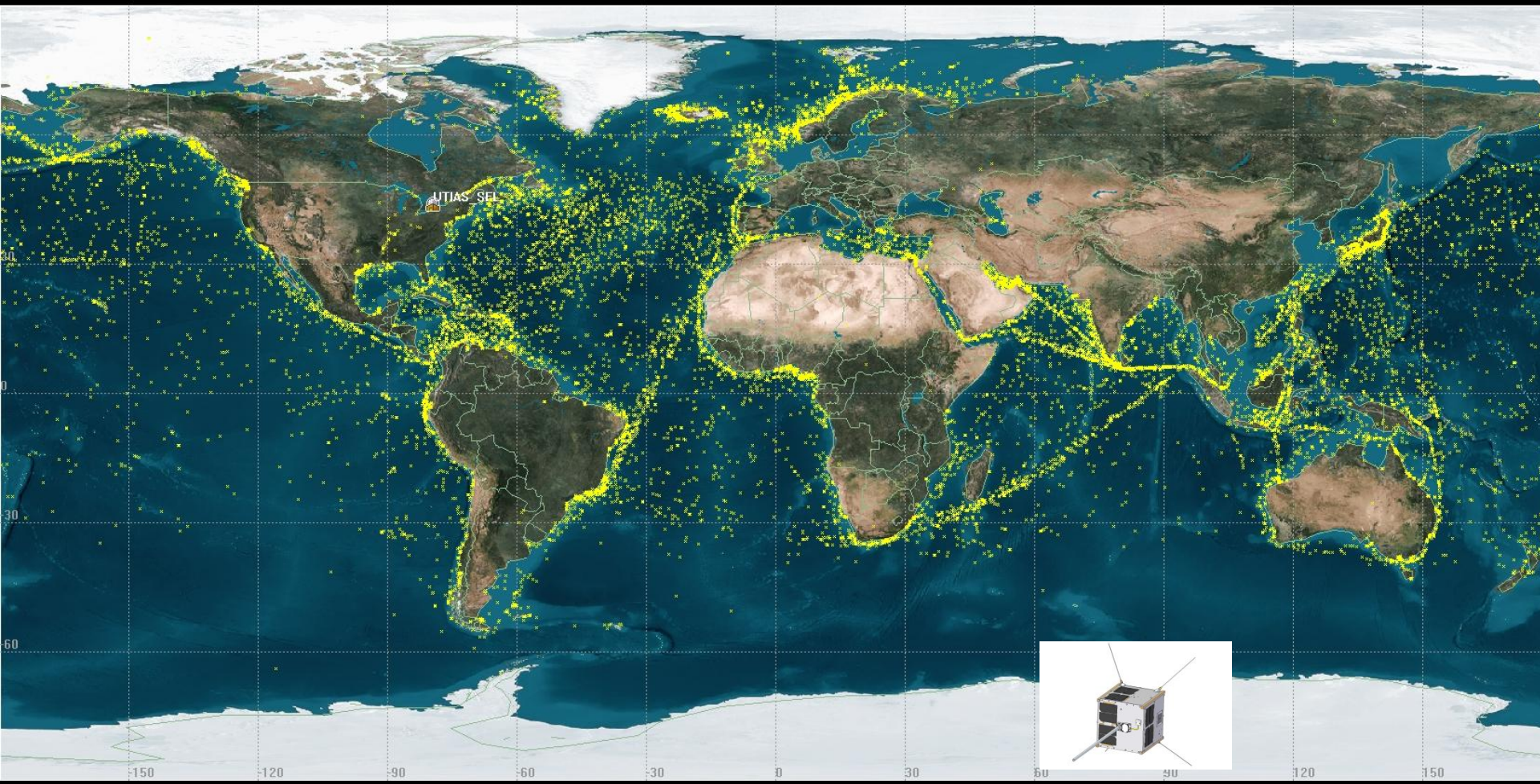
The First Space AIS Payload

NTS launch: April 2008

NTS Spacecraft

X-POD





Row Labels	Count of Country
Panama	2045
United States of America	1472
Liberia	1057
Norway	709
Japan	651
Bahamas	626
Marshall Islands	579
Russian Federation	524
Hong Kong	501
Malta	472
United Kingdom	472
Cyprus	372
Singapore	352
Canada	348
Greece	342
Antigua and Baruba	263
India	221
South Korea	221
Saint Vincent and the Gre	208
Netherlands	205
Germany	194
Iceland	173
Denmark	163
Brazil	144
China	143
Italy	141
Chile	135
Cayman Islands	125
Philippines	113
Indonesia	111
Spain	106
Malaysia	104
Vanuatu	100
Australia	98
Bermuda	93
Mexico	84
Alaska	81
Thailand	79
Belize	73
Turkey	73
Cambodia	68
Gibraltar	55
Netherland Antilles	51
France	48
Saudi Arabia	47
Kerguelen Islands	46
Belgium	40
Faroe Islands	37
Sweden	37
Vietnam	35
Venezuela	34
Egypt	33
Barbados	32
United Arab Emirates	32
Saint Kitts and Nevis	31
Iran	30
Malaysia	30
Ecuador	29
Luxembourg	28
Taiwan	27
Greenland	23
Bahrain	21
Portugal	21
Cook Islands	20
Qatar	20
Switzerland	20
Comoros	19
Croatia	19
Dominica	19
Falkland Islands	19
Ireland	18
Kuwait	18
Argentine	17
Bulgaria	17
Lithuania	17
Nigeria	17
Georgia	16
Sierra Leone	16
Papua New Guinea	15
Colombia	14
Finland	14
Jamaica	14
Honduras	13
North Korea	13
Sri Lanka	13
Morocco	12
Kiribati	11
South Africa	11
Tuvalu	10
Azerbaijani	9
Azores	9
Mongolia	9
New Zealand	9
Malaysia	8
Trinidad and Tobago	8
Israel	7
Jordan	7
Lebanon	7
Mauritius	7
Pakistan	7
Slovenia	7
Algeria	6
Bangladesh	6
New Caledonia	6
Syrian	6
Ethiopia	5
Latvia	5
Tonga	5
Uruguay	5
British Virgin Islands	4
Estonia	4
French Polynesia	4
Libya	4
Micronesia	4
Poland	4
Saint Barthelemy	3
Cape Verde	3
Kazakstan	3
Namibia	3
Wallis and Futuna Islands	3
Bolivia	2
Burkina Faso	2
Cuba	2
Djibouti	2
Ghana	2
Guadeloupe	2
Haiti	2
Myanmar	2
Paraguay	2
Romania	2
Seychelles	2
Turkmenistan	2
Albania	1
Austria	1
Christmas Islands	1
Dominican Republic	1
Gabonese	1
Gambia	1
Guyana	1
Macedonia	1
Martinique	1
Monaco	1
Mozambique	1
Nauru	1
Nicaragua	1
Niger	1
Palau	1
Peru	1
Saint Lucia	1
Saint Paul and Amsterdam	1
Senegal	1
Solomon Island	1
Somali	1
Tanzania	1
Yemen	1
Zanzibar	1

Over 16,000 ships – tiled 90 second snapshot

COM DEV AIS

WHAT CAN AIS BE USED FOR?

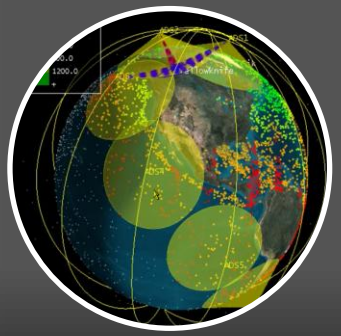
Surveillance and Security

Arctic Vessel Monitoring

Search and Rescue

Environmental Monitoring

exactEarth



Satellite Constellation

- Detects AIS Class A Signals
- Initial Satellite launches – mid 2010
- Full 6 satellite constellation by 2014
  - <2 hour global revisit rate
  - Secure downlink

Earth Stations

- Downlink signals
- Data Pre-Processing
- 3 Initial Earth Stations
- 3 additional stations for full constellation
- Secure transfer to Data Center

Data Center

- Located in highly secure facility in Canada
- Decollide signals into AIS messages
- Convert messages into industry standard formats
- Filter and forward messages to Customer

Customer Delivery

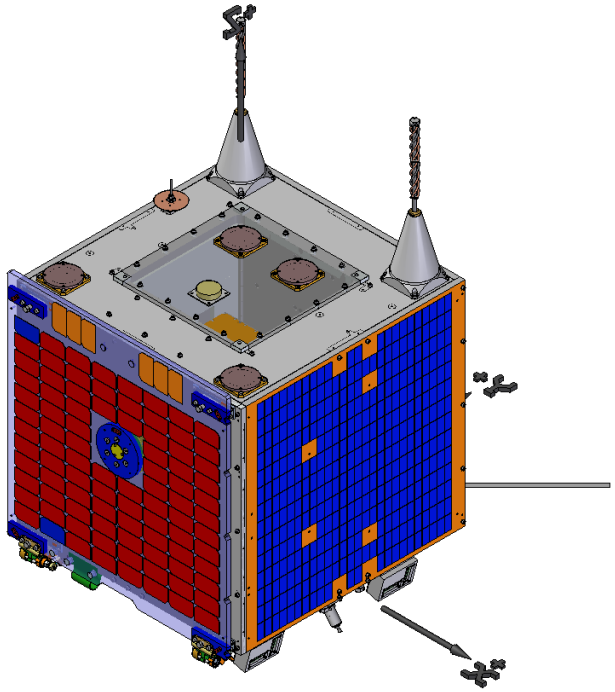
- Industry standard files such as NMEA, OTH-Gold KML, or XML
- Only authorised data is distributed
- Commercial Display System
- Integration into Custom Display System

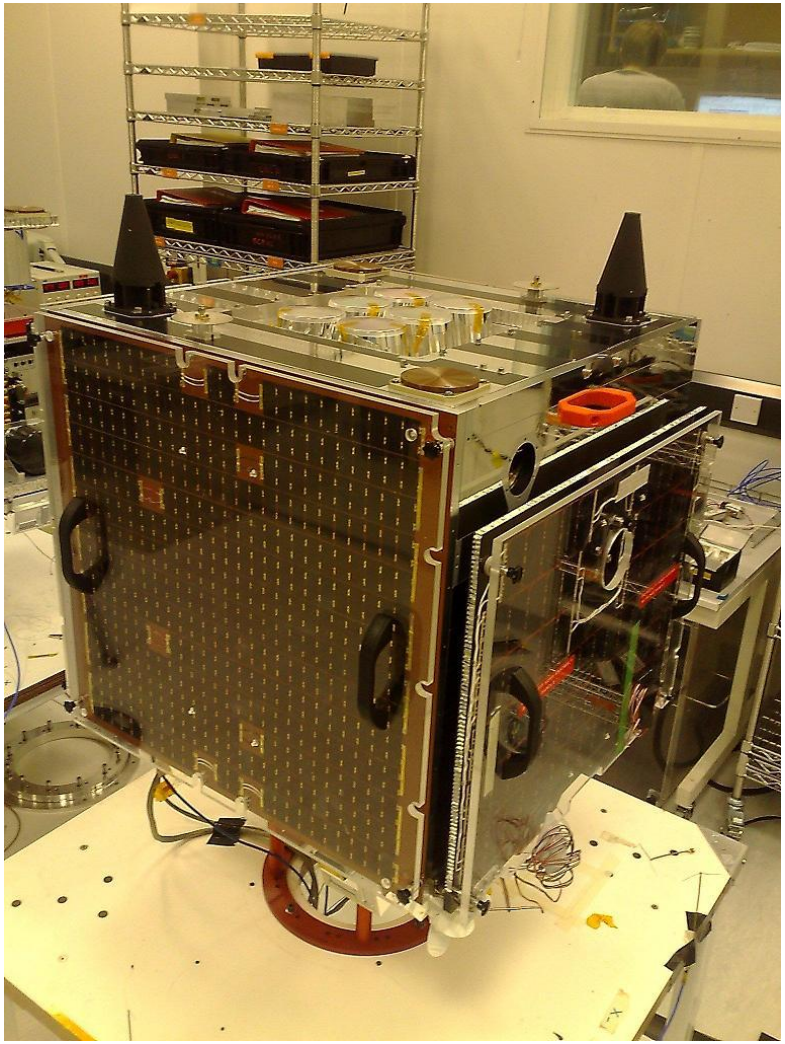
End-to-End, Highly Secure Solution for Increased Maritime Domain Awareness

THE SPACECRAFTS?

ADS-1B

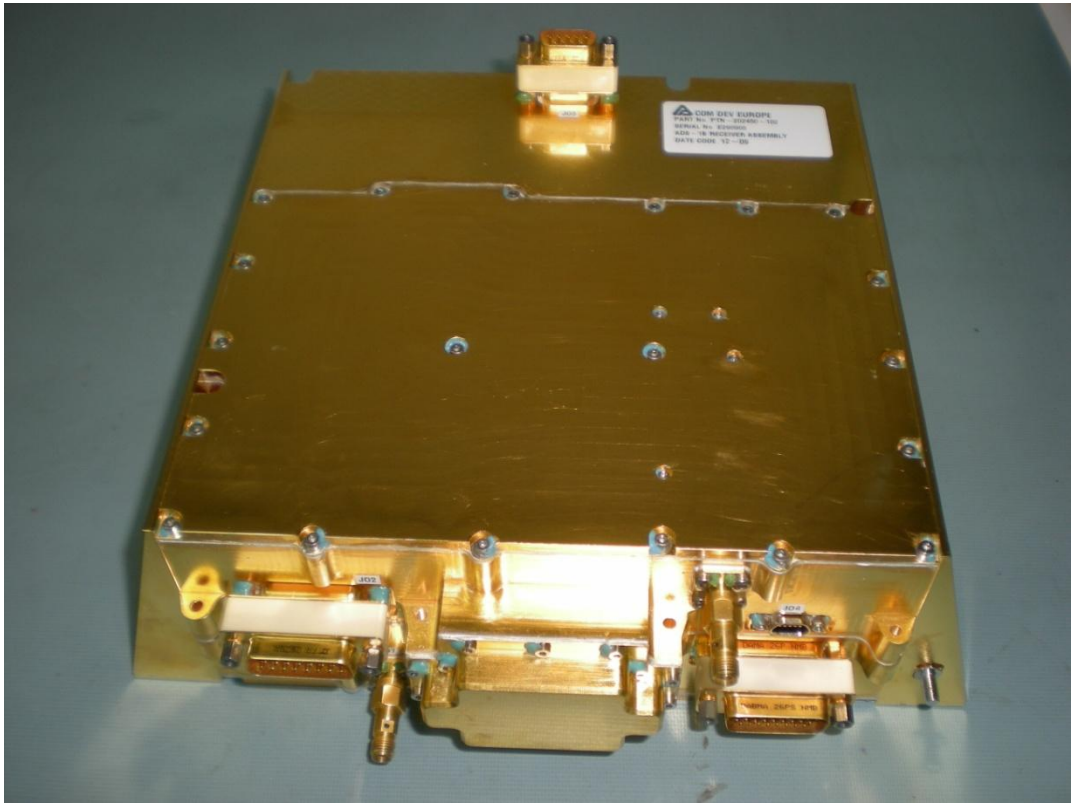
- Microsatellite
- S-Band TM/TC
- C-Band Payload Downlink
- 2 Polarizations / 4 Channels





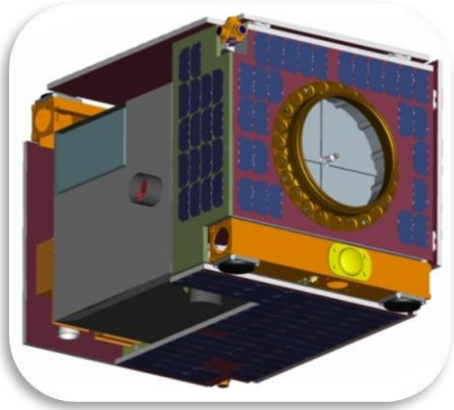
Hosted Indian Payload (HIP-1)

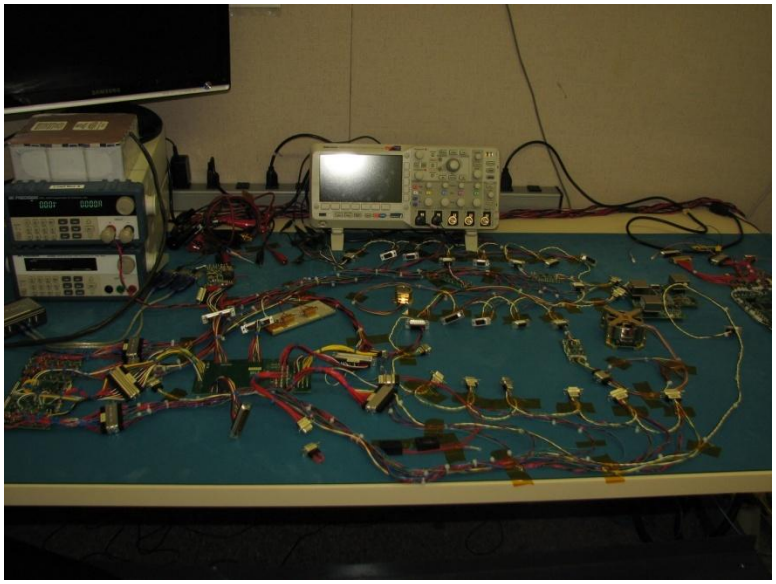
- Resource Sat-2 (ISRO)
- Two Polarizations / 4 Channels
- S-Band Data Downlink



M3MSat

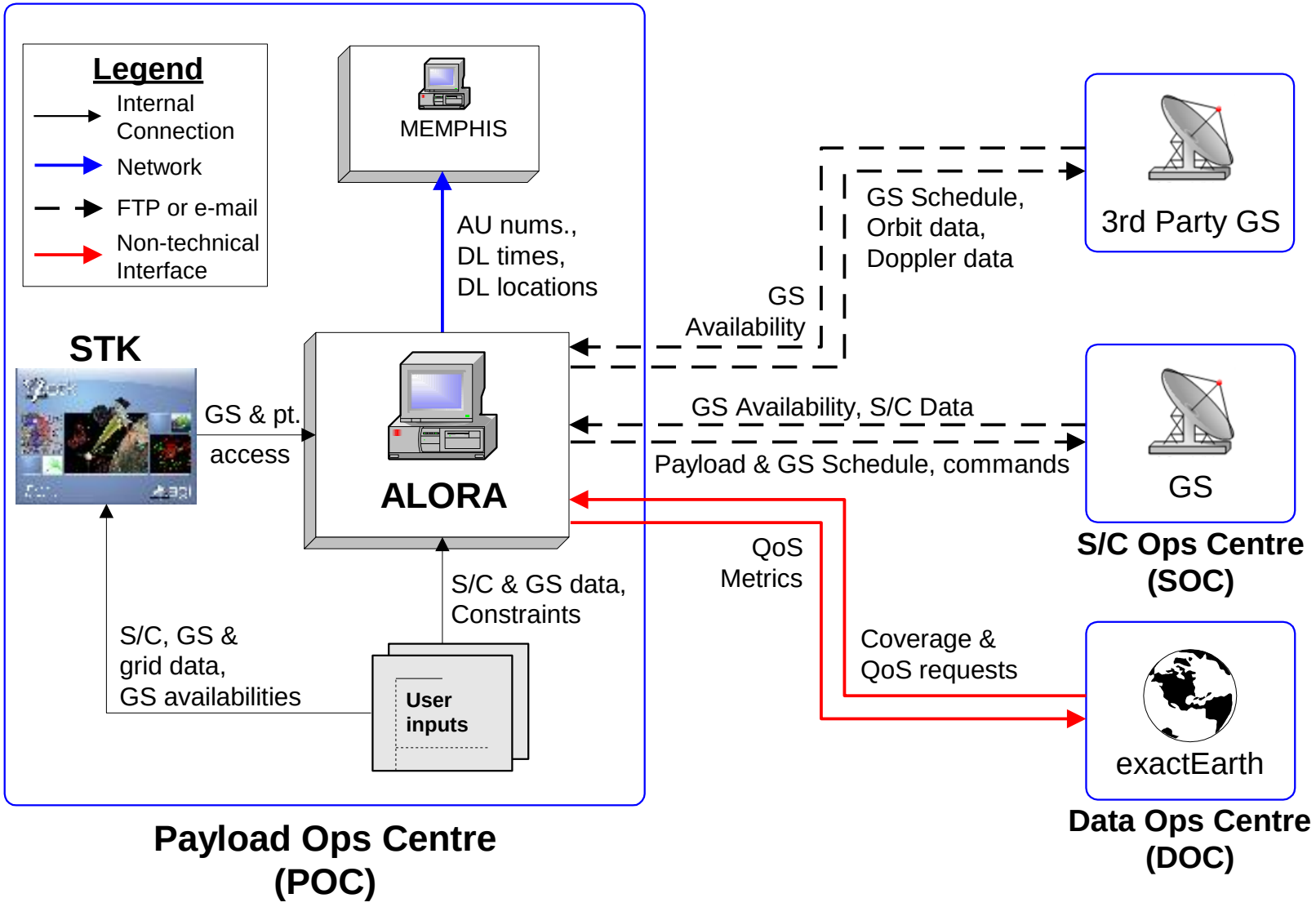
- Microsatellite (95Kg)
- S-Band TM/TC
- C-Band Payload Downlink
- 2 AIS Payloads each with2 Polarizations / 4 Channels
- Low Data Rate Systems (Trial Experiment)



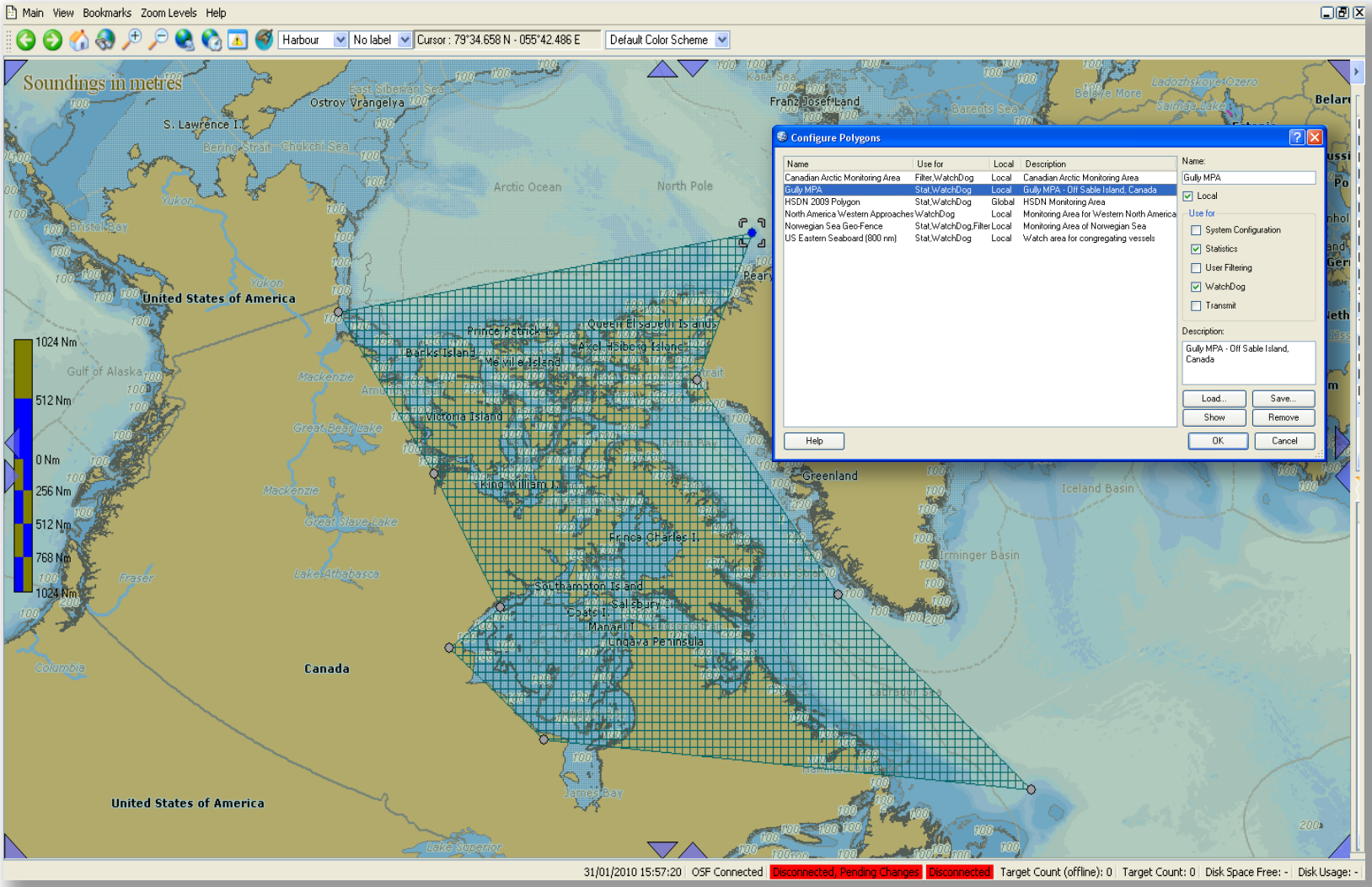


HOW IT ALL WORKS?

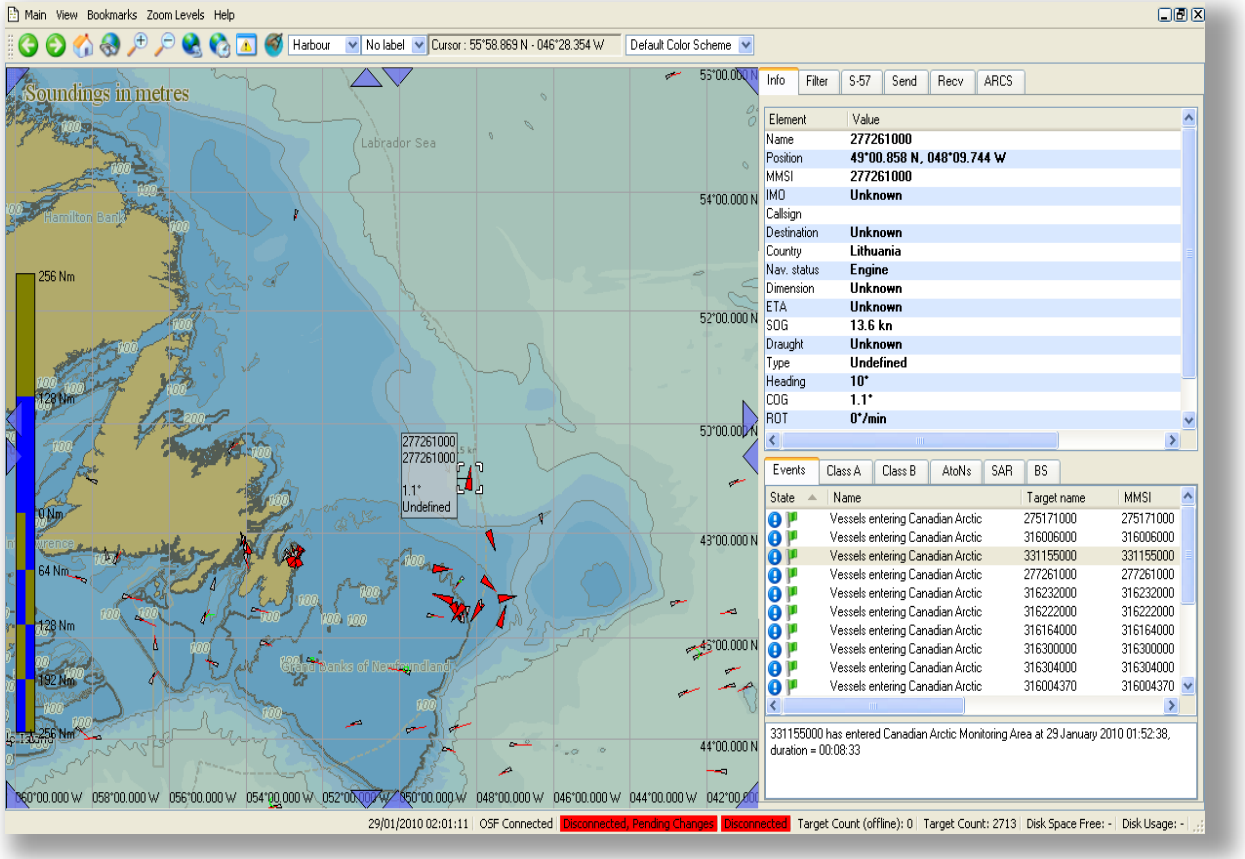
Operations


Legend
Internal Connection
Network
FTP or e-mail
Non-technical Interface
MEMPHIS
AU nums.,
DL times,
DL locations
STK
GS & pt. access
ALORA
S/C & GS data,
Constraints
S/C, GS & grid data, GS availabilities
User inputs
Payload Ops Centre (POC)
GS Schedule, Orbit data, Doppler data
GS Availability
3rd Party GS
GS Availability, S/C Data
Payload & GS Schedule, commands
GS
S/C Ops Centre (SOC)
QoS Metrics
Coverage & QoS requests
exactEarth
Data Ops Centre (DOC)

Define and Monitor Areas of Interest

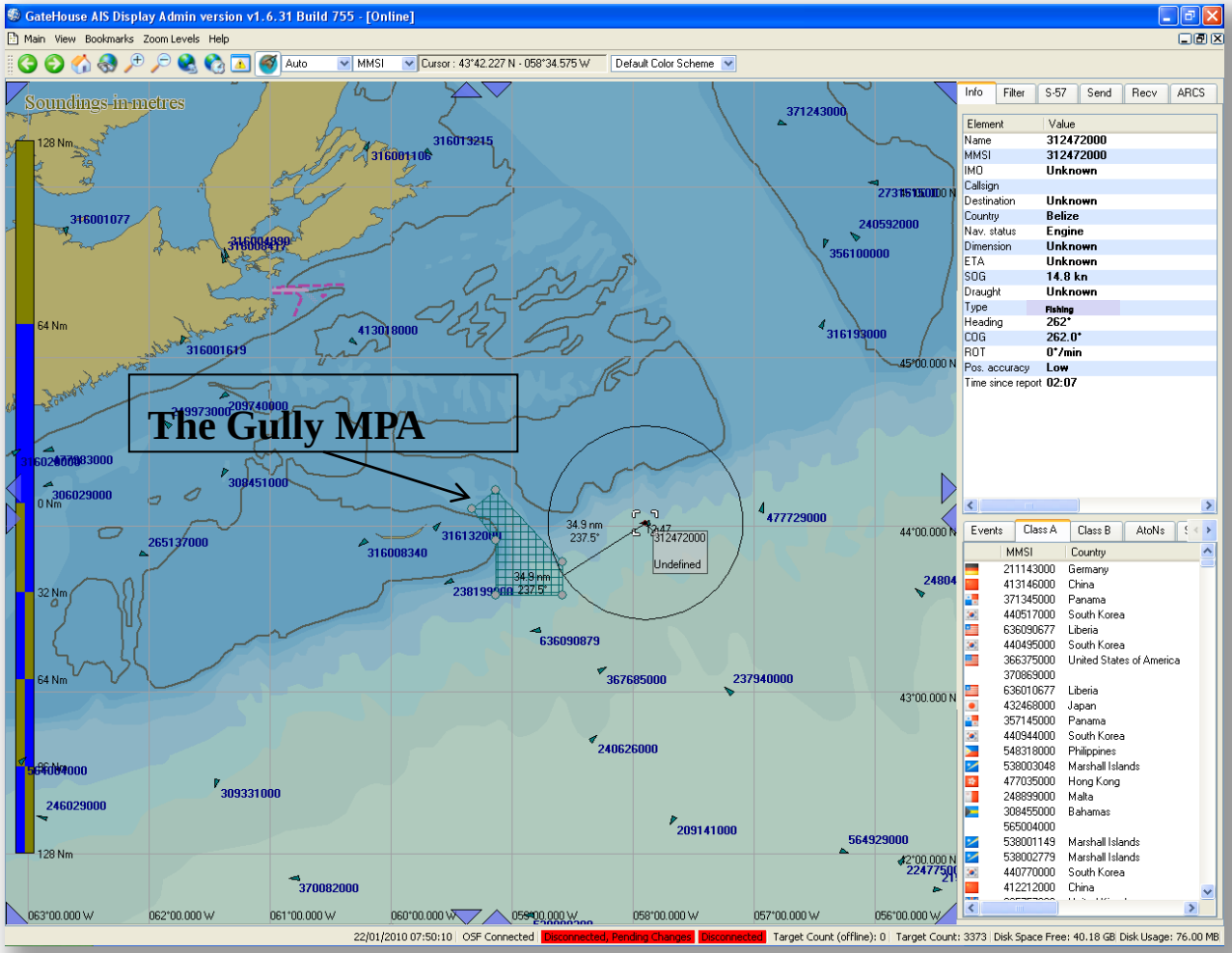


Monitor Coast Lines



- Monitor vessel traffic in costal areas
- Feed back to SAR aircraft
- Historical tracking of ships in and out of costal ports

Monitor Marine Protected Areas



- Monitor vessel traffic in sensitive areas
- Automated Alerts based on:
  - Approaches
  - Intrusions and Exits
  - Vessel Speed
- Historical and Statistical Data of MPA traffic

Questions?