OceanObs '99

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Towards New Platform Technology for Sustained Observations

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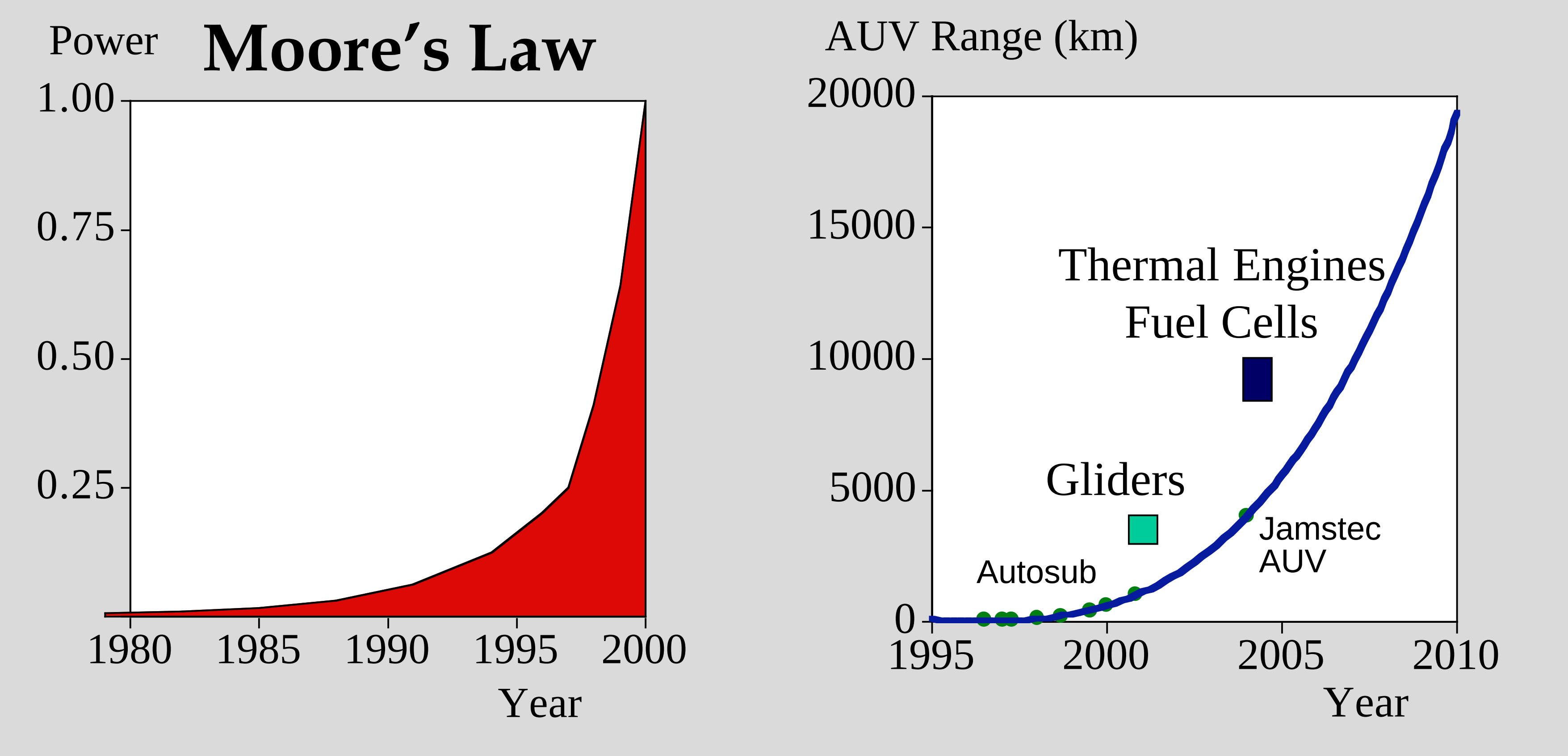
Outline

- ❑ Moore's Law applied to AUVs?
- ❑ 2D - 4D AUVs - a family of platforms
- ❑ Industry drivers for low cost observations
- ❑ Science Drivers : Process studies
  Long sections
  Polar oceanography
- ❑ Observatories
- ❑ Sensors
- ❑ Communications, Energy
- ❑ Costs
- ❑ Legal Issues

AUV Range Prediction 1995-2015



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2-D AUVs - Moored Profilers

- WHOI M&M 1 Mm on ca. 3 kWh
  - Depth range 25 - 5000 m
  - Total Mass 42-49kg including FSI CTD + ACM
  - Power cost ~ $3,500 per deployment, or $3.5 per km
  - Proven prototypes: 501 profiles 100-1400m; cluster of 3 deployed; 60 profiles 1300m-4300m … other users

Courtesy WHOI web site, D Frye

- Licensed to McLane Research Labs. Inc., Falmouth
- European project YoYo 2000 producing multidisciplinary upper ocean profiler
- Others ...

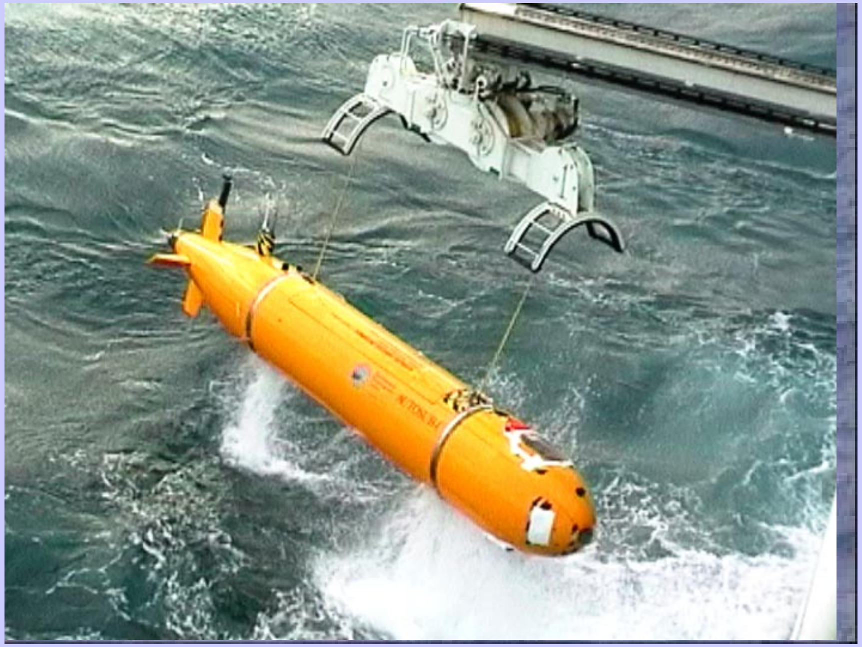
3-D AUVs - Autonomous Surface Craft

- *SASS* from SeaSpeed Engineering Ltd., U. Southampton, UK
  - UK SeaSense LINK project
  - Semi-submersible design
  - Stability optimised for seabed survey sonars
  - Range 600-1000km at 12-15kt
  - 5 m long
  - 200 kg payload space
  - 1/3 scale prototype trials complete; commercial build expected - perhaps 2001

- *Caravella* from U. Azores; IST, Lisbon; Simrad, Norway etc.
  - EU Eureka project E!1850
  - Self righting surface craft
  - Satellite data & control
  - Range > 1300km at 4kt
  - 7m long, 2m wide & 6m high
  - Autonomous CTD winch
  - Commercial launch in 2002

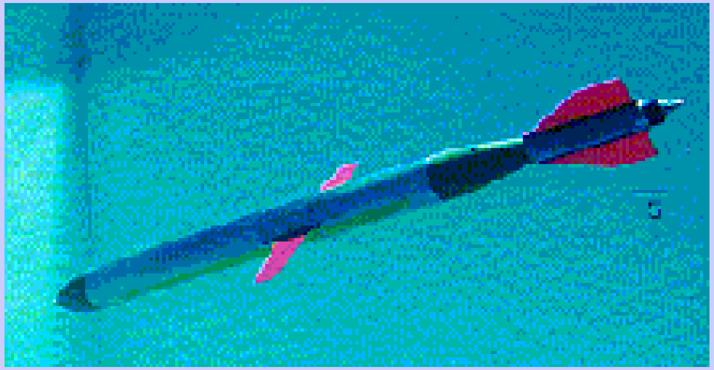
Courtesy Eureka web site

4D AUVs - Subsurface autonomous craft



- ❑ Lagrangian Drifters & Profilers
- ❑ Gliders
- ❑ Self propelled vehicles
  - Neutral or positively buoyant
- ❑ Largest Class
  - Janes Underwater Technology '99 lists 60+ vehicles
  - Offshore industry, telecoms, defence, science, monitoring
    Hugin, Odyssey, OE X, R-One Robot, Martin, LDUUV, Autosub

Gliders



Courtesy Webb Research web site

- ❑ The global AUV?
- ❑ 3 projects sponsored by ONR
- ❑ Webb Research
  - Electro-hydraulic buoyancy change, or
  - Thermal engine buoyancy change (SLOCUM)
- ❑ SIO Davis/Sherman '*Spray*'

2 m long *48.2 kg* *0.9 m wingspan*

1500 m max depth	*17 - 26 cm/s horiz Velocity*
CTD sensors	*1650 - 4900 horiz. Range*
500 - 900 cycles	

- ❑ U. Washington - Eriksen vehicle

Towards low cost from economy of scale
Offshore Industry drivers for AUVs

- ❑ Massive increase in costs with ROV technology beyond 3000 m
- ❑ Oil majors pushing service companies to source AUV technology
- ❑ First service company AUV ITT in mid 1998 (Fugro) - 7 responses
- ❑ One oil major sees $100m saving over 5 years using AUVs
- ❑ Drive will be for seabed survey, but spin-offs expected e.g docking technology, reliability

'Main' suppliers

Daewoo (S. Korea)
Simrad (Norway)
ISE Research (Canada)
Northrop Grumman (US)
Lockheed Martin (US)
GEC Marconi (UK)
Maridan (Denmark)
STN Atlas (Germany)
Bluefin (US)
Mitsubishi H.I. (Japan)
Chelsea Inst. (UK)
...

HUGIN - a commercial untethered AUV

- ❑ Project began 1995
- ❑ Partners: Statoil, Simrad, Norwegian Defence Research Est. & Norwegian Underwater Intervention
- ❑ Very strong & credible team
- ❑ Prototype HUGIN I used by a *client* in Oct '97, sale Oct'99
- ❑ Primary purpose: Seabed & Pipeline Survey - EM3000
- ❑ Design emphasises real-time communications & ease of handling

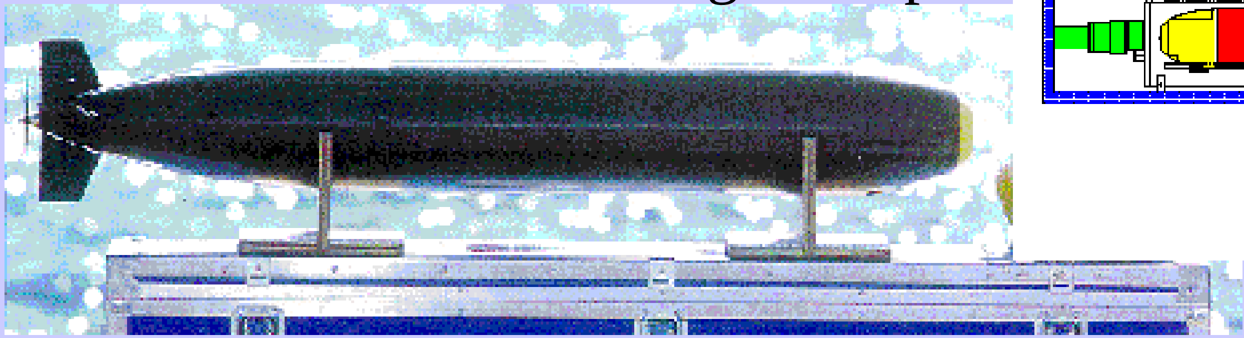
Courtesy NUI web site

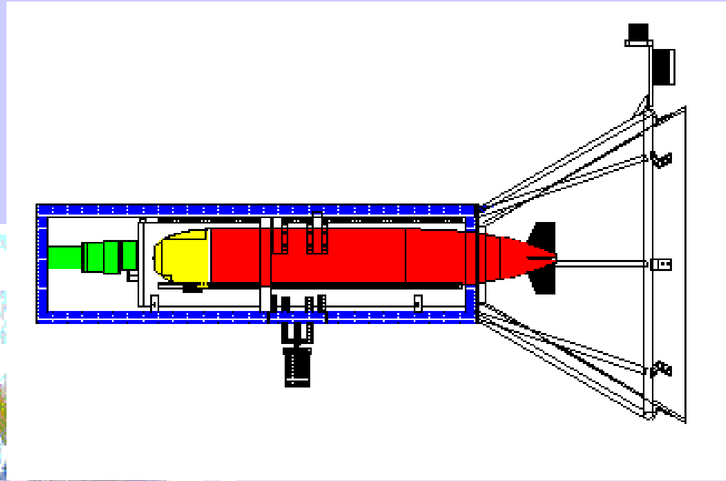
- ➜ HUGIN I and II rated to 600 m
- ➜ Weigh ~ 700 kg
- ➜ Length 4.8 m, low drag shape
- ➜ HUGIN I 3 kWh NiCd battery for 6 hr endurance
- ➜ HUGIN II 18 kWh semi fuel cell - 36 hr or 260 km

AUVs for Process Studies

- ❑ Labrador Sea deep convection : MIT Odyssey
- ❑ Sicily Strait overflow: SOC Autosub-2
- ❑ Upper Ocean turbulence & Langmuir studies
  - SOC Autosub-2 & FAU Ocean Explorer II
- ❑ Continental Shelf Observatories (LEO-15) : WHOI Remus

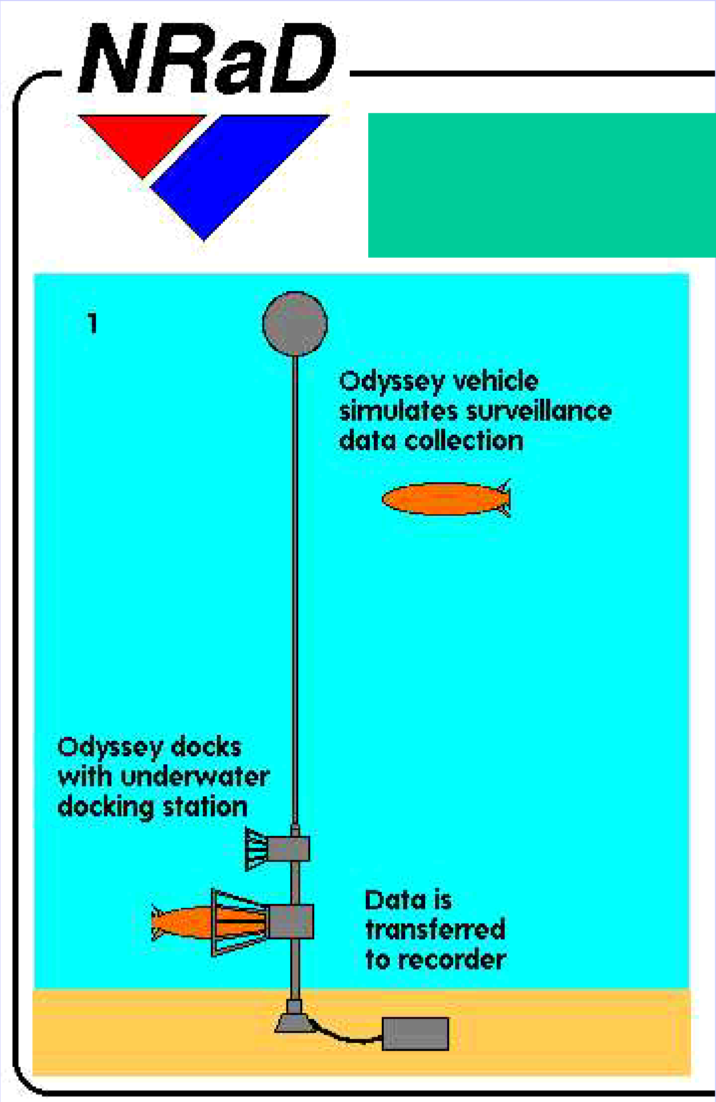
REMUS & Docking concept





Courtesy WHOI web site

AUV Docking Technology

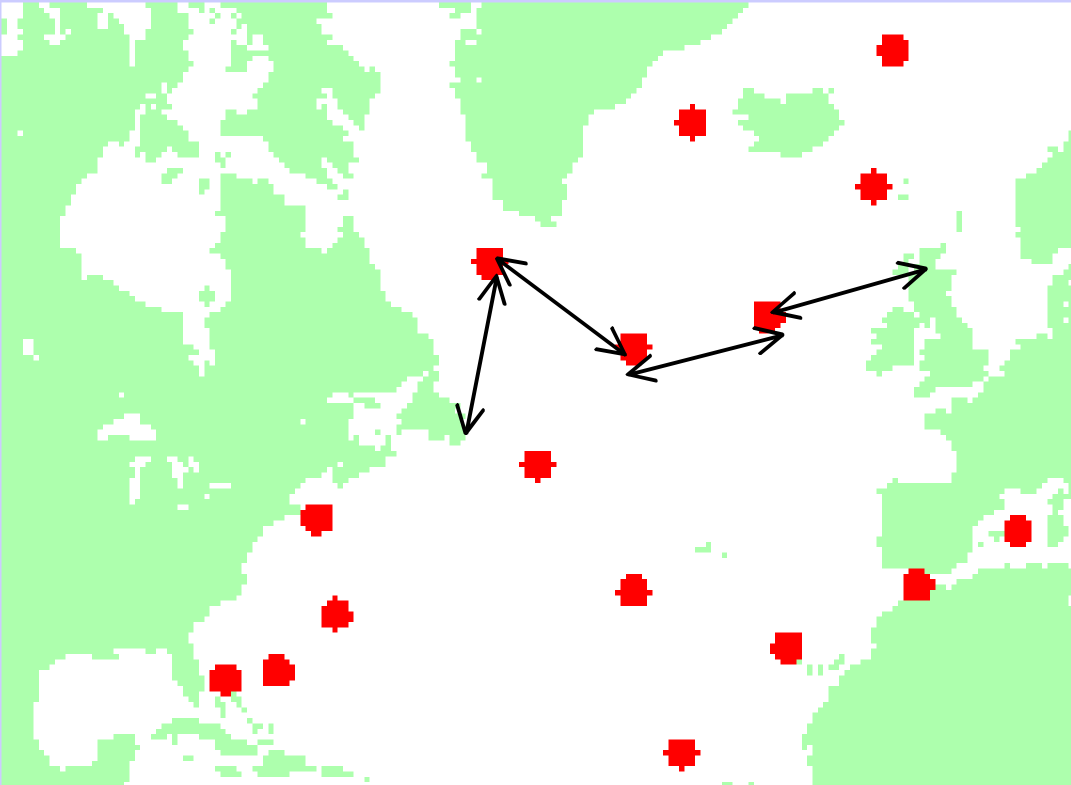


- MIT Odyssey - Distributed Surveillance Sensor Network; Autonomous Ocean Sampling Network; Labrador Sea 1998
- FAU Ocean Explorer (shelf)
- EURODOCKER consortium

Courtesy MIT Sea Grant & NRaD web sites

Ocean Observatories - AUV stations?

N Atlantic possible sites



1000 km

- Illustrative tracks of 1000 km between observatories
- 1000 km possible with secondary cells
- Docking Stations possible
- Battery recharging possible
- Data download possible
- Reliability?

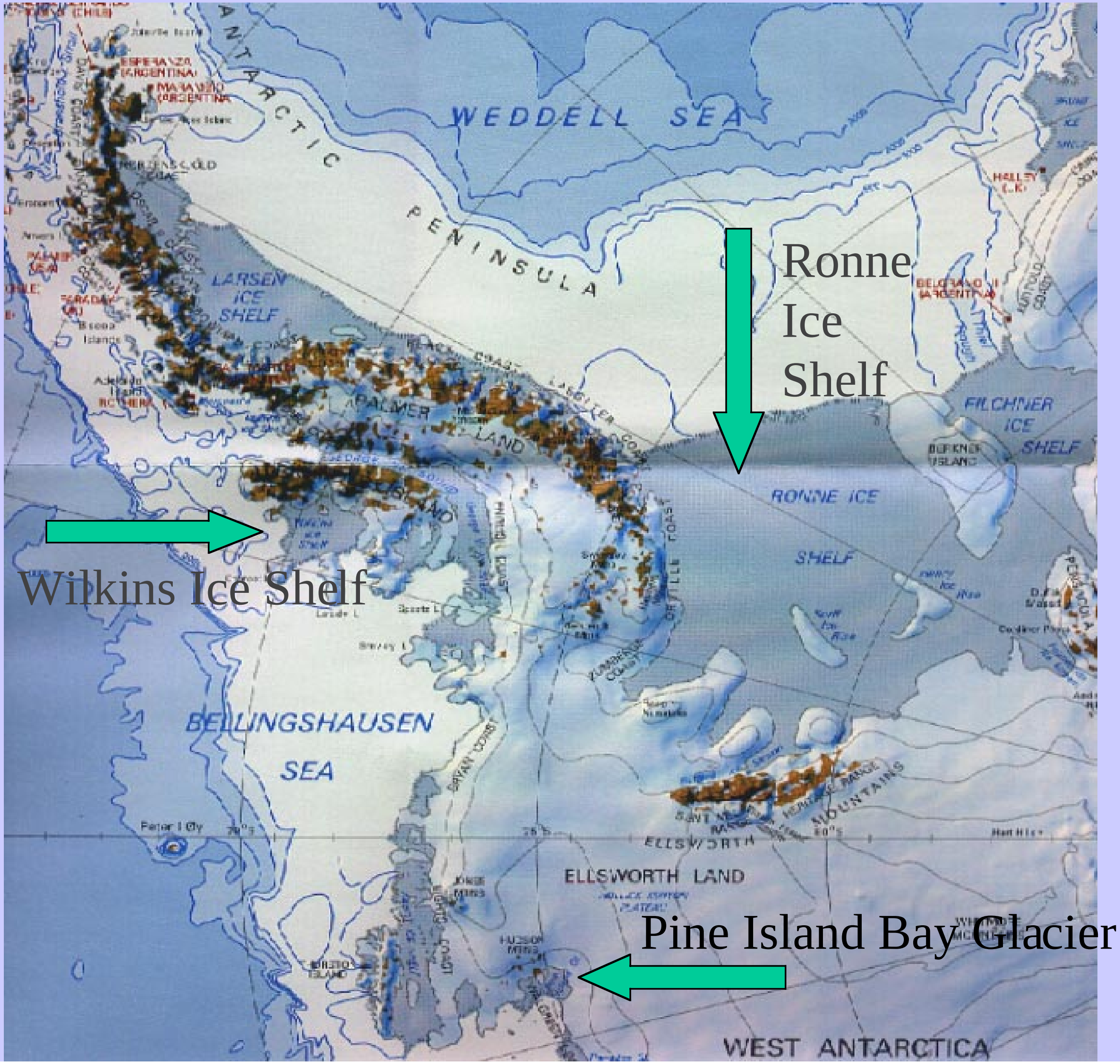
From http://uop.whoi.edu/geo.html dated 21 Sept 1998

AUVs for Polar Applications

'Otherwise Impenetrable Environments'

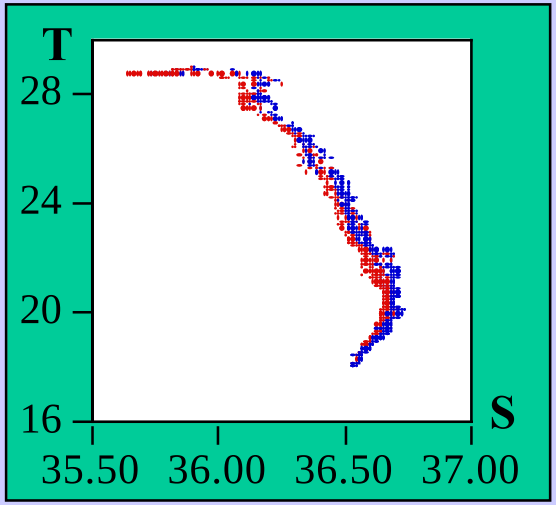
- MIT Sea Grant & partners ALTEX - Atlantic Water inflow to the Arctic Ocean: Odyssey-based AUV
- JAMSTEC Long-range AUV - towards trans-Arctic sections
- SOC Autosub - Under Ice Shelves proposal 2001-06
- AWI (part way through proposal cycle)
- CSIRO Hobart, Amery Ice Shelf studies, could use AUV
- Italian Antarctic Programme, Terra Nova Bay developing the SARA AUV

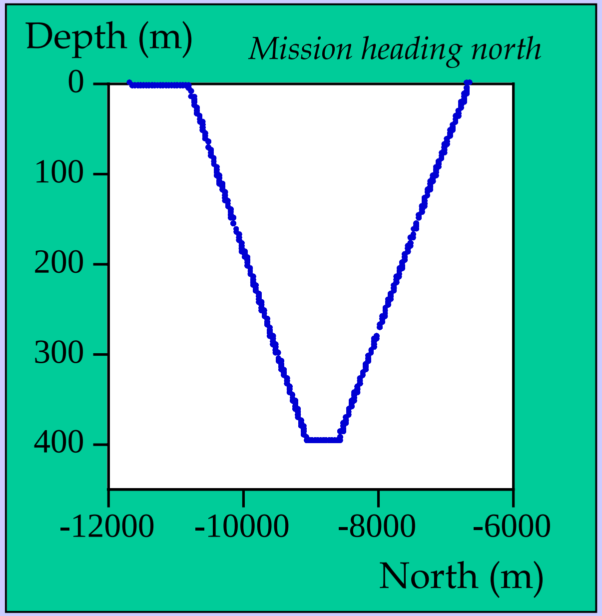
Under Antarctic Ice Shelves



CTD Sensors issues for AUVs

- ❑ Fouling, stability, time constants, thermal gradients
- ❑ Limited use yet by critical scientists
- ❑ Favourable early CTD comparisons by MIT Sea Grant
- ❑ Similarities to and differences from towed vehicles
- ❑ Autosub data sets illustrate number of CTD problems
- ❑ AUV Water samplers available, but unproven
- ❑ Role of deep water masses as calibration points





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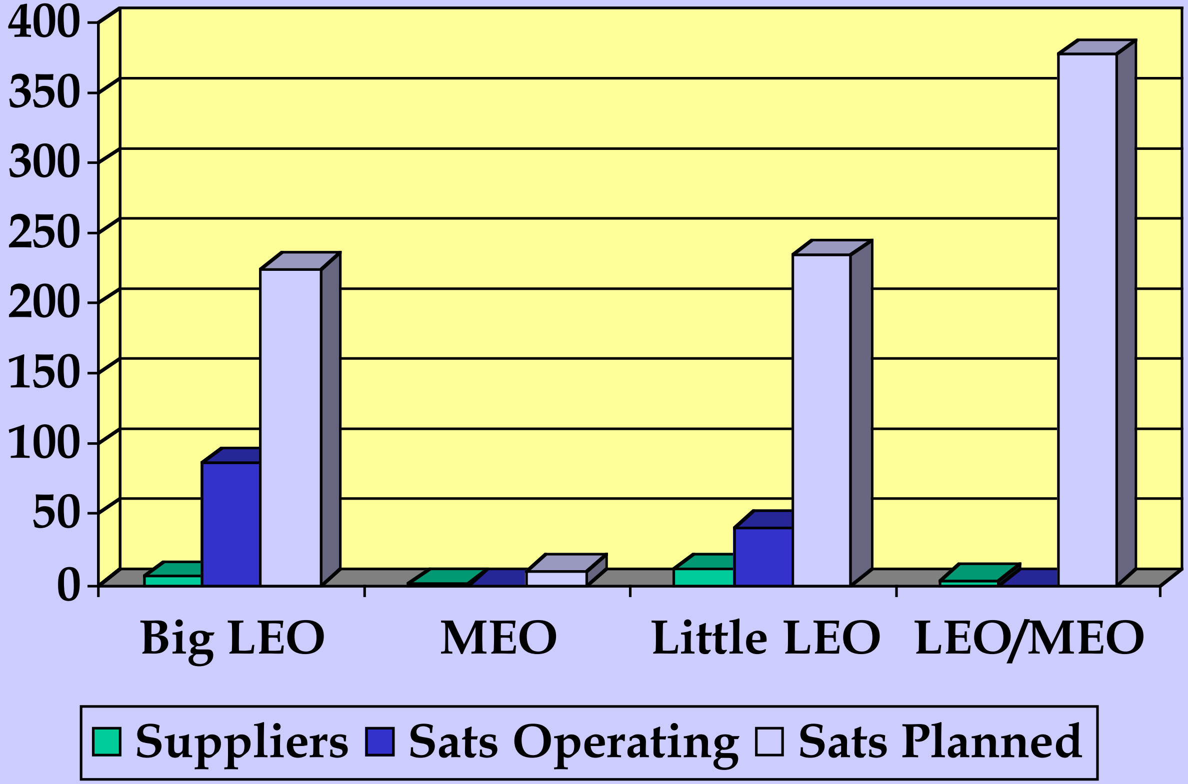
Communications

❑ Over next 5 years - (possibly) large choice of (low cost) satellite communications services



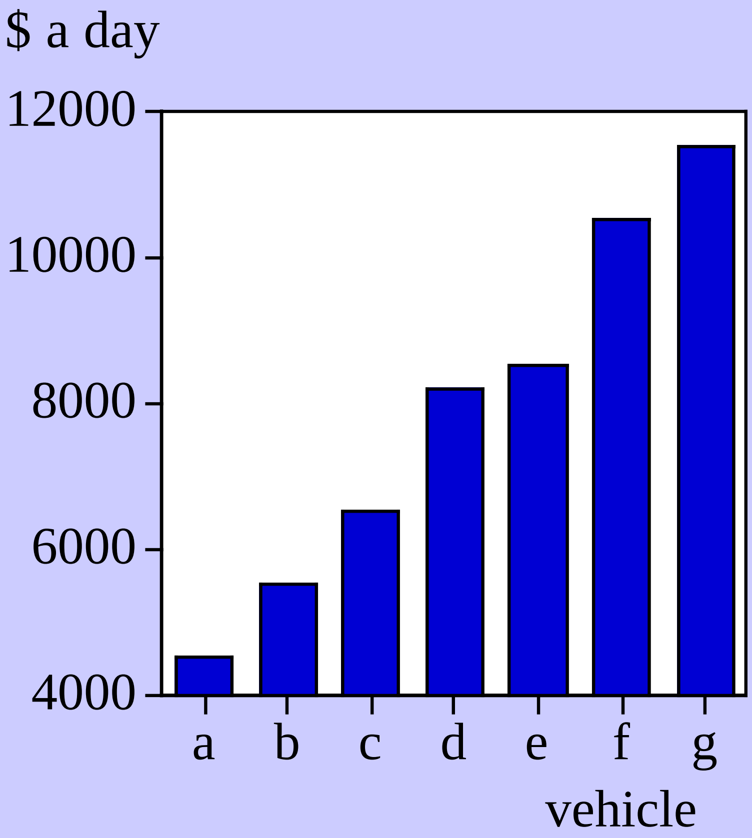
Big LEO & MEO
Telephony

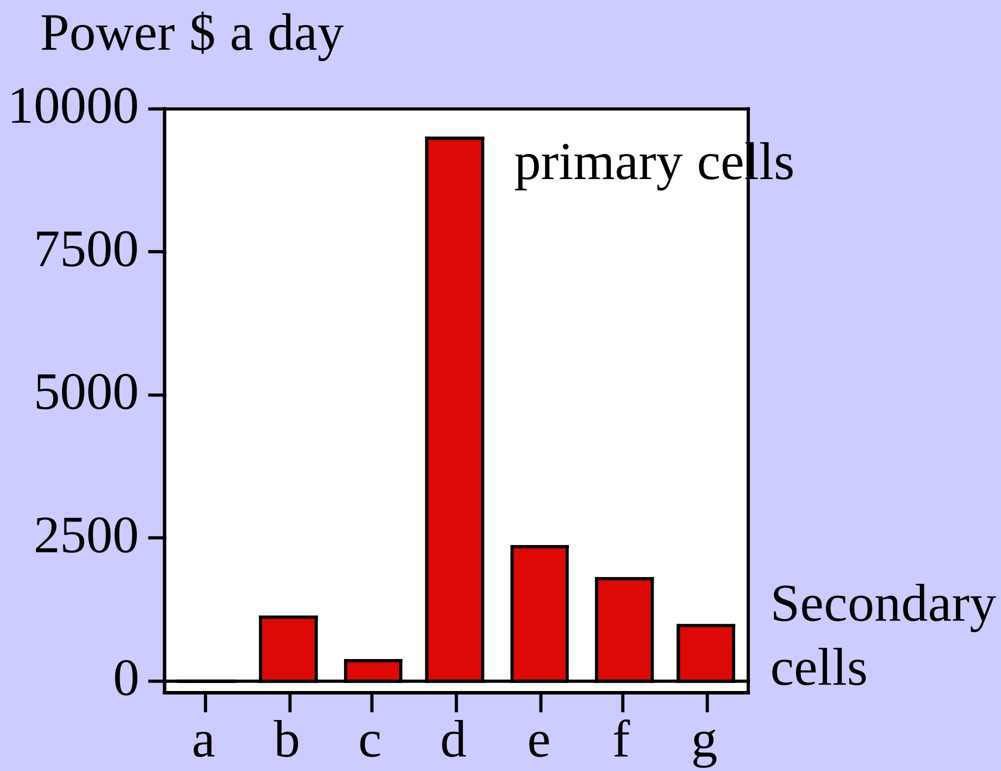
Little LEO
Messaging

LEO/MEO
Broadband Comms

Courtesy David Meldrum, DML & ISIR Newsletter, April 99

AUVs: Cost of operation





From an unpublished analysis by a commercial company

Present & Future Energy Supply Options

Autosub Power Consumption 350 -750 Watts
Max. Wt. 300 kg (GFRP vessel) to 700 kg (CFRP vessels)

	GFRP	CFRP	$/km*
❑ Lead Acid Secondary			
● 20 - 40 Wh/kg :	7.5		$0.20
❑ Manganese Alkaline Primary			
● ~ 120 Wh/kg :	38	100	$19
❑ Silver Zinc Secondary			
● 130 - 196 Wh/kg	39-59	91-137	$14
● 15 - 30 usable cycles			at 30 cycs

- ❑ Lithium Polymer Secondary: 155 - 170 Wh/kg **$0.50**
- ❑ Lithium Ion Secondary: 100 - 120 Wh/kg
- ❑ Fuel Cells; Semi-fuel Cells 16,000 Wh/kg H_2 in carbon nanotubes

* excl. overheads

Legal Issues

- Status in National & International law unclear
  Even ODAS buoy convention still in draft after 20+ years
- No AUV is registered or classified, but some insured
- An AUV *might* be considered a ship for some legislation, yet *not* for others
- Obligations and responsibilities of owners, operators, programmers & launchers unclear

- Way forward …
  - Develop Code of Practice in the community
  - Include procedures, define responsibilities, review document regularly …
  - Demonstrate knowledge of the legal framework
  - UK has AUV Legal Issues Working Group within Society for Underwater Technology; SOC updating 1989 legal advice
  - Tackle nationally before going international

Summary

- Rapid pace of technological advance in vehicles & communications; multiple sources, multiple concepts
- Propelled vehicles energy cost per km of $0.50 likely to be achievable in next decade
- Glider cost-per-profile similar to XBT if amortised over 5000 profiles
- Jury still out on the reliability of vehicles, feasibility of commercial builds, operational overheads, long-term data quality
- Continuing engineering trials and process study experiments will provide more experience
- By 2003: powered AUV range > 2000 km; depth > 3000 m; gliders proven to 5000 km; docking routine for some