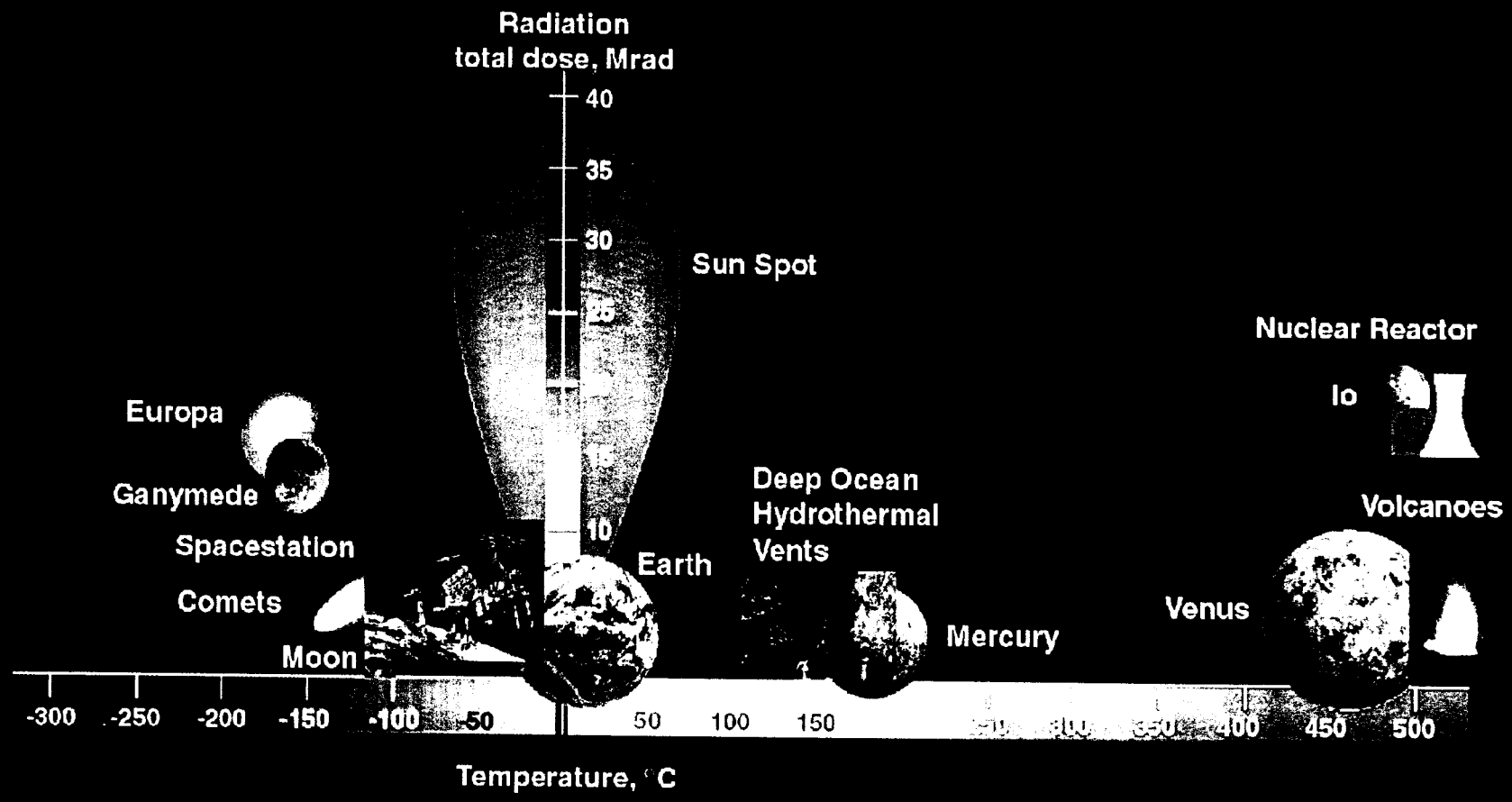

**Deep Space Communication and
Navigation Symposium
(DESCANSO)**

**Europa:
Extreme Communication
Technologies for Extreme Conditions**

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Communication Issues

- **Long intransit time, plus 1 yr deorbit in intense Jovian radiation environment, will expose communication system to >20Mrad total dose radiation**
- **Surface ice temperature @ -170°C, gradually warming to -5°C @ ice-liquid interface**
- **Tight mass constraints require that avionics operate with no insulation and no shielding**
- **Ice transceivers/mole/instrument pods will see pressures as high as 100 atmospheres**
- **Ice transceiver design spec**
 - **10 cm dia quad-dipole antenna (3 cm thick)**
 - **Data rate - 10 Kb/sec**
 - **Ice impurity level - 13 ppm salt (earth)**
 - **Data volume - 5 MB/day**
 - **Duty cycle- 4000 sec/day**
 - **Power rqmts- 120 mW/burst (1.3 W total with efficiency losses)**
 - **Power source- Bismuth-Telluride radioisotope power stick, (2 cm dia., 9 cm long)**



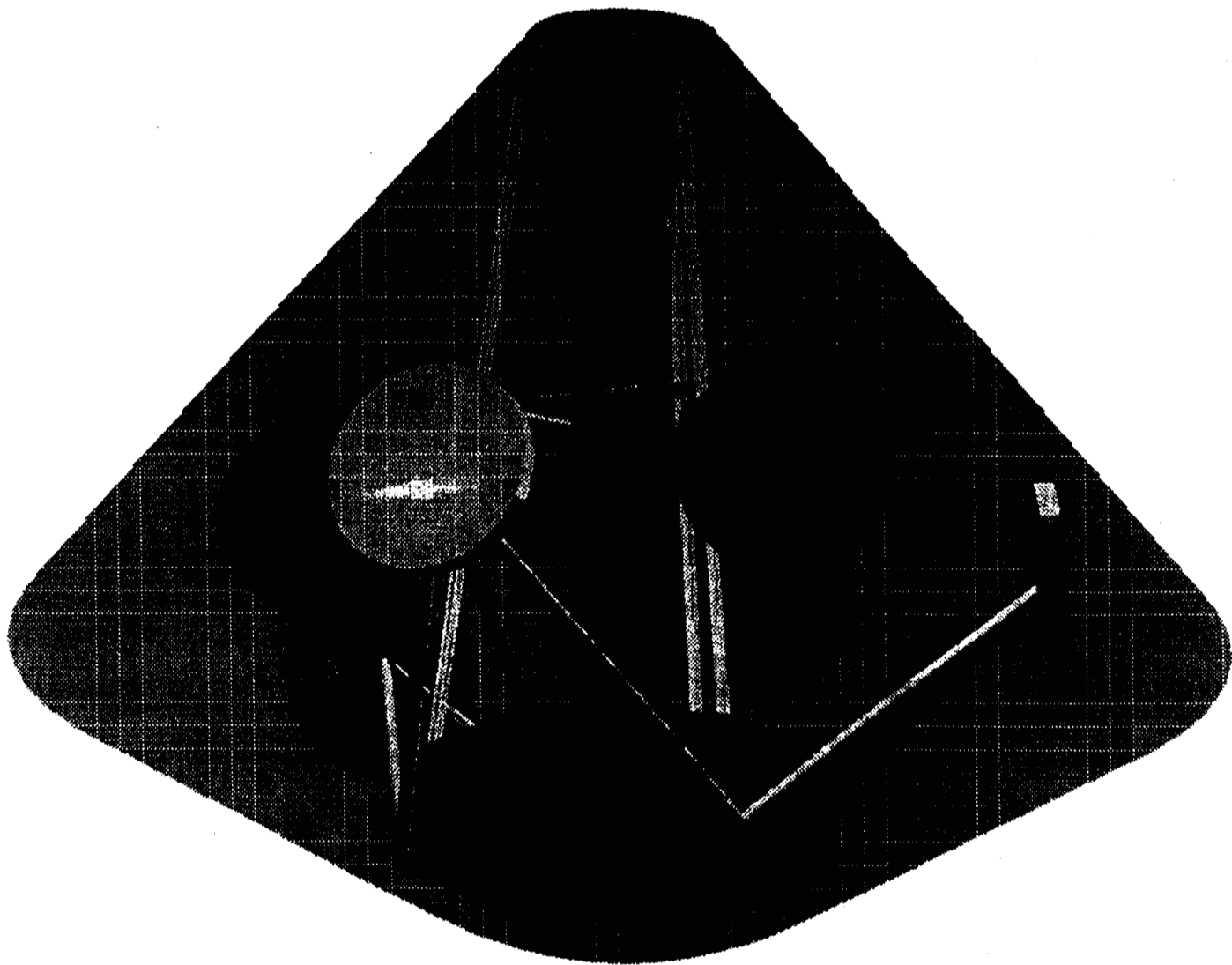
Basis For Europa Cryo/hydro-bot Study

- **Not much work has been done to identify all options available for science payload delivery to Europa**
- **Europa represents a unique opportunity to explore an ice/water environment unlike any other outer planet environment**
- **Classical robotic approaches like augering are limited in depth**
- **Cryo-Hydro Integrated Penetrator System (CHIRPS) represents the new wave of robotic vehicles which can allow deep in-situ sampling access to many planetary and small bodies**
 - Europa
 - Io
 - Titan
 - Ganymede
 - Mars polar regions
 - Comets
- **The CHIRPS study helps identify needed technologies for out-year planetary road-map missions such as those above**

Mission Design/Assumptions

- **Delta-2 injects SC to low earth orbit**
- **SEP moves SC to high apogee elliptical transfer orbit (63.4km)**
- **Small chemical AV used for Earth escape ($C3=34\text{km}^2\text{sec}^2$; large SC mass (700kg vs. 280kg) used for conservatism)**
- **Jettison SEP stage/tanks**
- **Earth gravity assist after 2yrs w. mid-course correction of 400m/sec**
- **Coast to Jupiter (total transit time of 4.5yrs including transfer orbit/gravity assist)**
- **Europa deorbit/land (1yr)**

Note: Two Jupiter/Europa fly-by piggyback missions have been worked by TeamX and results strongly suggest that piggyback mass penalty (on the order of -200kg) does not allow a viable science payload (approximated at 3-4kg) to be placed on Europa surface--dedicated lander/CHIRPS appears better way to go.

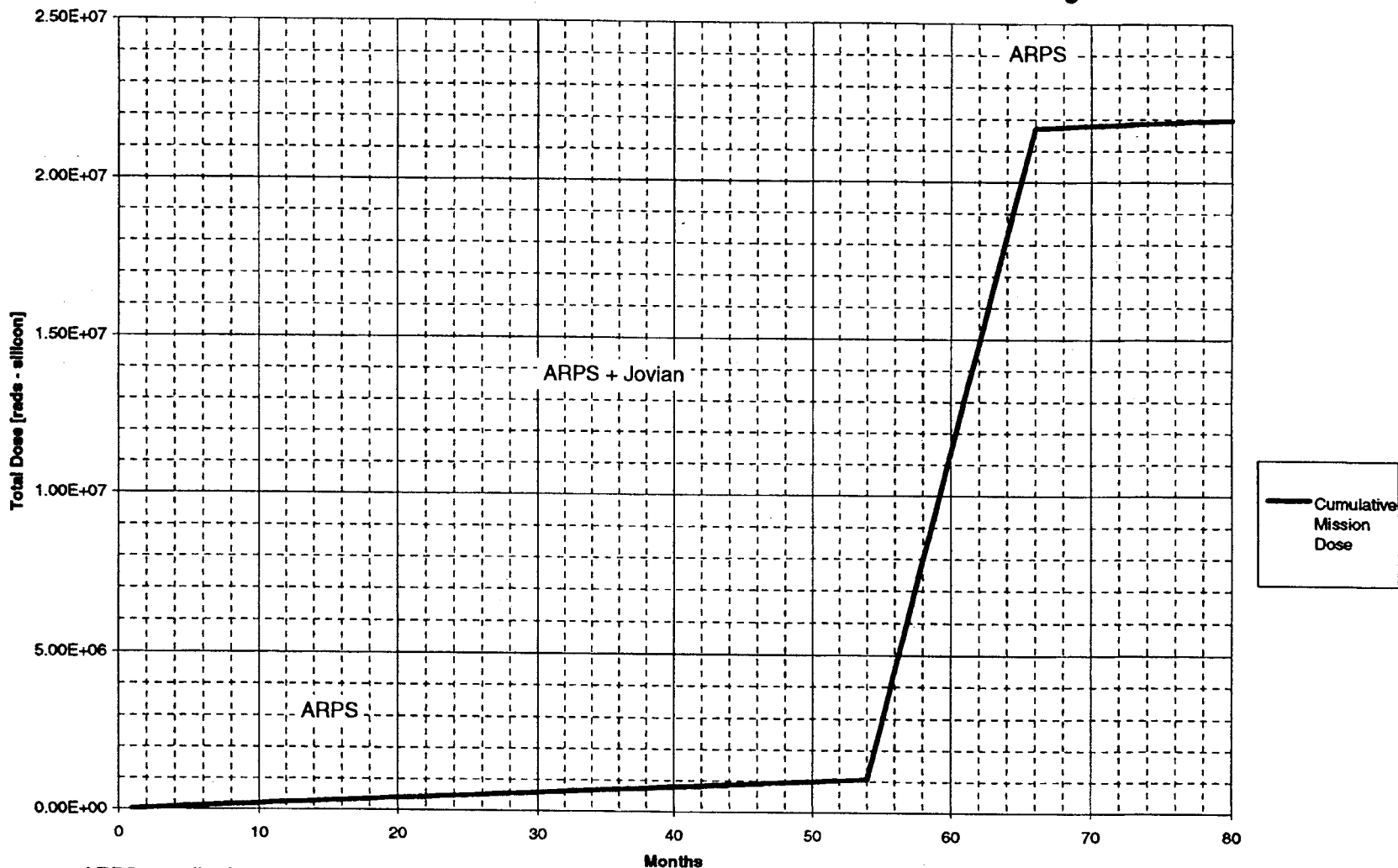




SC Mass Breakdown

Component	Mass (kg)
SEP PV array/support HIW	226
SEP/GN&C/Xe tank	270
Star 48V	1893
EEO/escape/EGA propellant	1100 (propellant margin)
Lander	250
CHIRPS	30 (8kg margin)
Europa insertion propellant	1230
Margin	<u>124</u> (approx 3%)
Total	5123 (Delta-2 7920 pyld limit 5126kg)

Europa Mole Penetrator Mission Radiation Profile - Preliminary Results



ARPS contribution to total dose after 80 months = 7.7 %

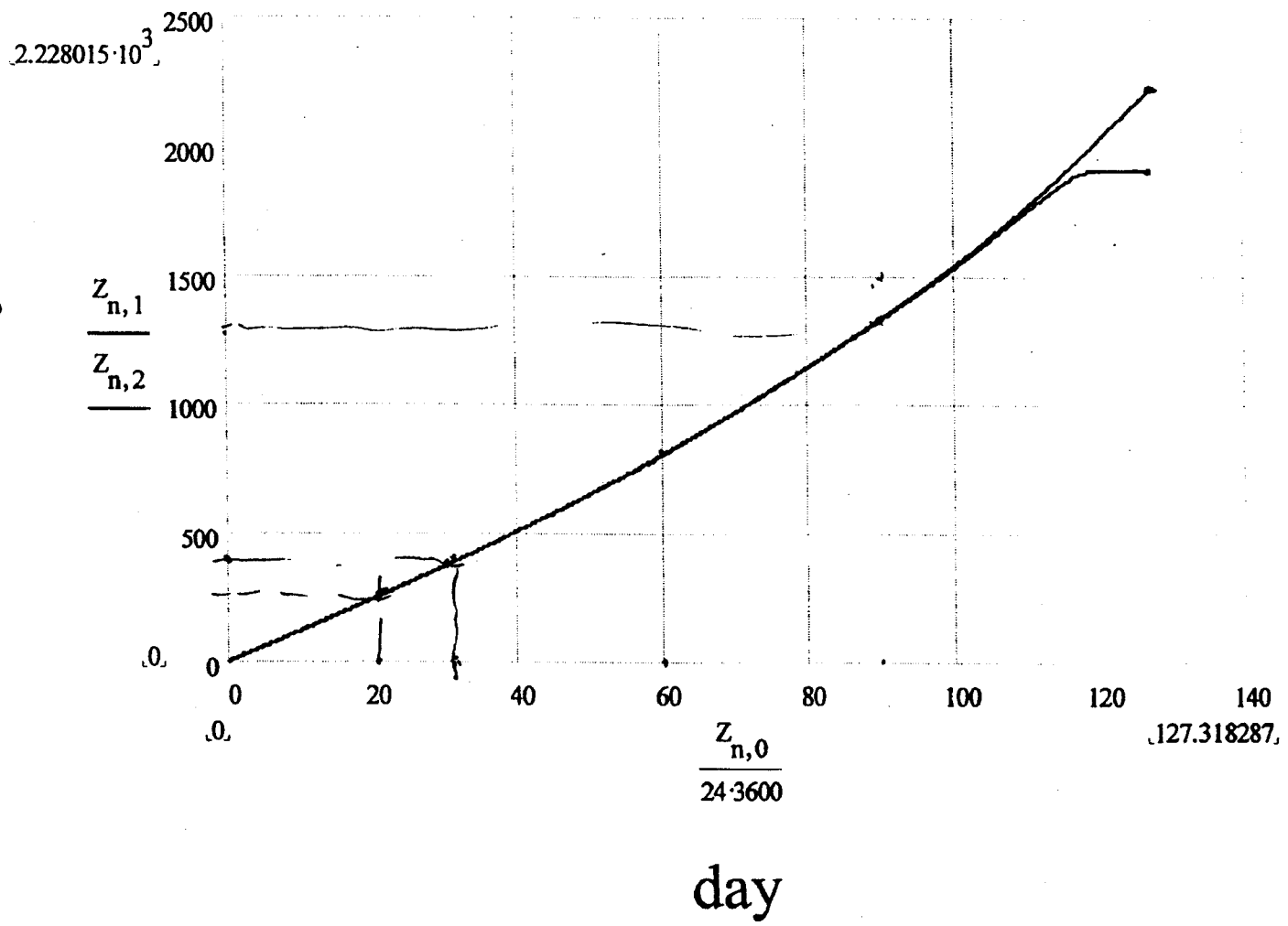


Results of Fluid Dynamics Modeling

- CHIRPS modeled as a long cylinder with two spherical ends approximately 1m long, 12cm dia
- Amount of heat required to displace melt water and maintain thin (i.e., 1mm) layer of water around probe is approximately 1kw
- Key variables effecting melt dynamics
 - Probe cross sectional area
 - Delta temperature between t -infinity and t -probe surface
 - Ice properties (i.e., pressure, temperature, coefficient fric/viscosity)
 - Depth
- Projected mm energy required to meet above melt water displacements is approx .8kw
- Projected melt rate is .5km/mo
 - Must incorporate advanced rad hard technology to extend orbital/surface life (TEMIC)
- Probe designed with 1kw thermal to insure $\geq .5$ km/mo melt rate (vehicle accelerates as it penetrates deeper into ice since Δ temp between ice/vehicle decreases)
- Probe control sequence
 - Heat nose to create melt water void
 - Flash heat mid section to reduce friction on shell caused by ice pressure/ice viscosity and initiate slip
 - Heat vehicle rear to allow release of transceiver
 - Vehicle steered by using acoustic imaging at nose to detect obstacles and selective heating of surface quadrants to allow directed melting

Depth vs. time, Q=1100 W

Front,
Back,
m

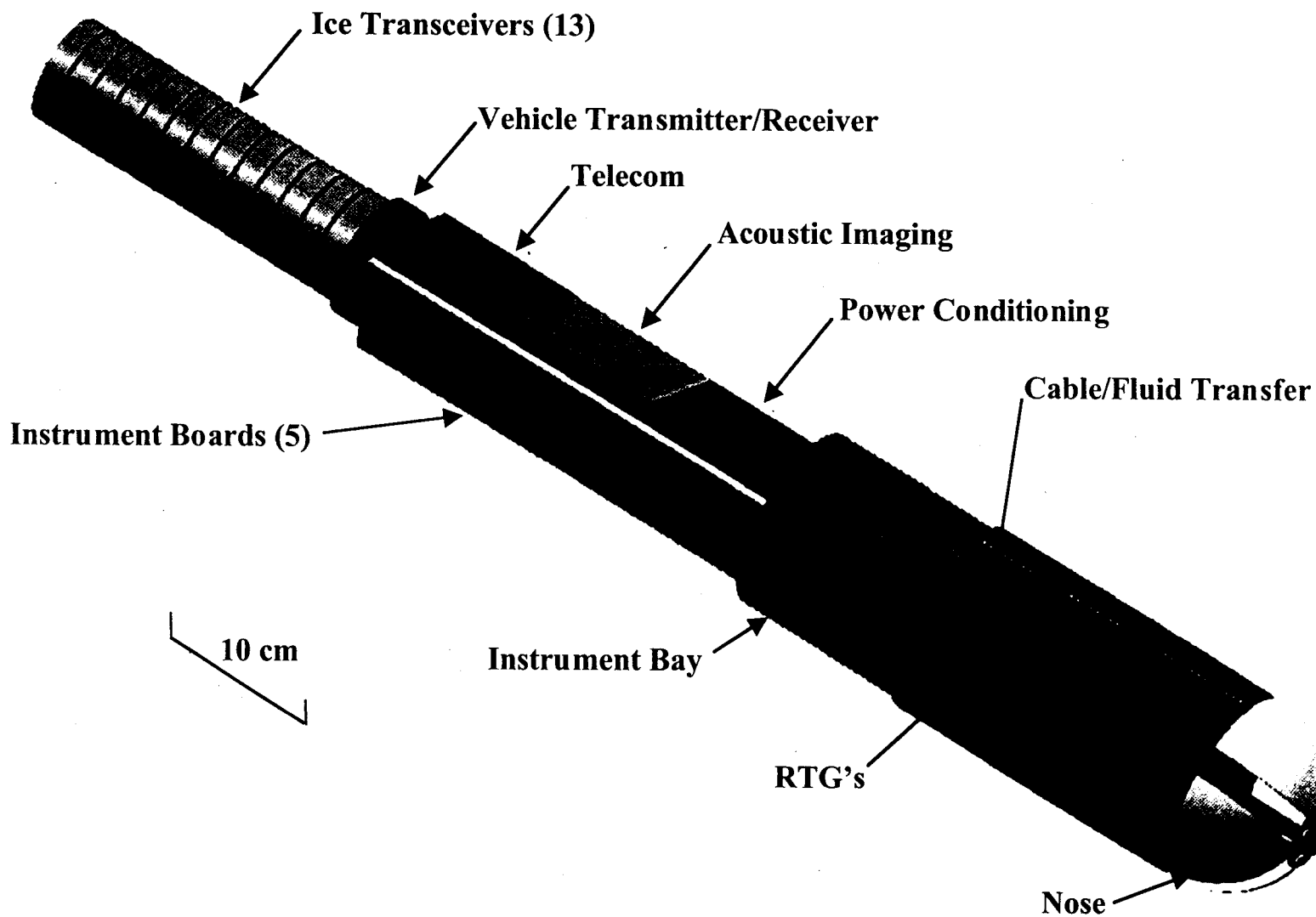




CHIRPS Design

- **Vehicle dimensions**
 - Diameter- 12cm
 - Length- ≤ 1 m
- **Configuration**
 - Diameter driven by fit with existing AR') isotope energy packaging
 - Vehicle slightly tapered to take advantage of additional force vector resulting from normal pressure forces exerted by ice and to help offset variable friction forces due to variations in ice consistency, contaminants, and temperature
 - Vehicle c.g. placed close to nose to allow greater stability (similar to existing Philberth probe designs)
 - Length driven by fit with existing Delta 2 lander configurations
 - Instrument bay insulated from ARP units, receives melt water sample from liquid cooling core via an external channel & membrane which allows melt water seepage/collection by passive water/ice refreeze pressure
 - Instrument bay contains up to 5 science instruments
 - Instrument bay can hold 1-3 pods containing science instruments for release at the ice-water IF
 - Control electronics and instrument device drivers mounted on rigid triangular strut structure aft of the instrument bay

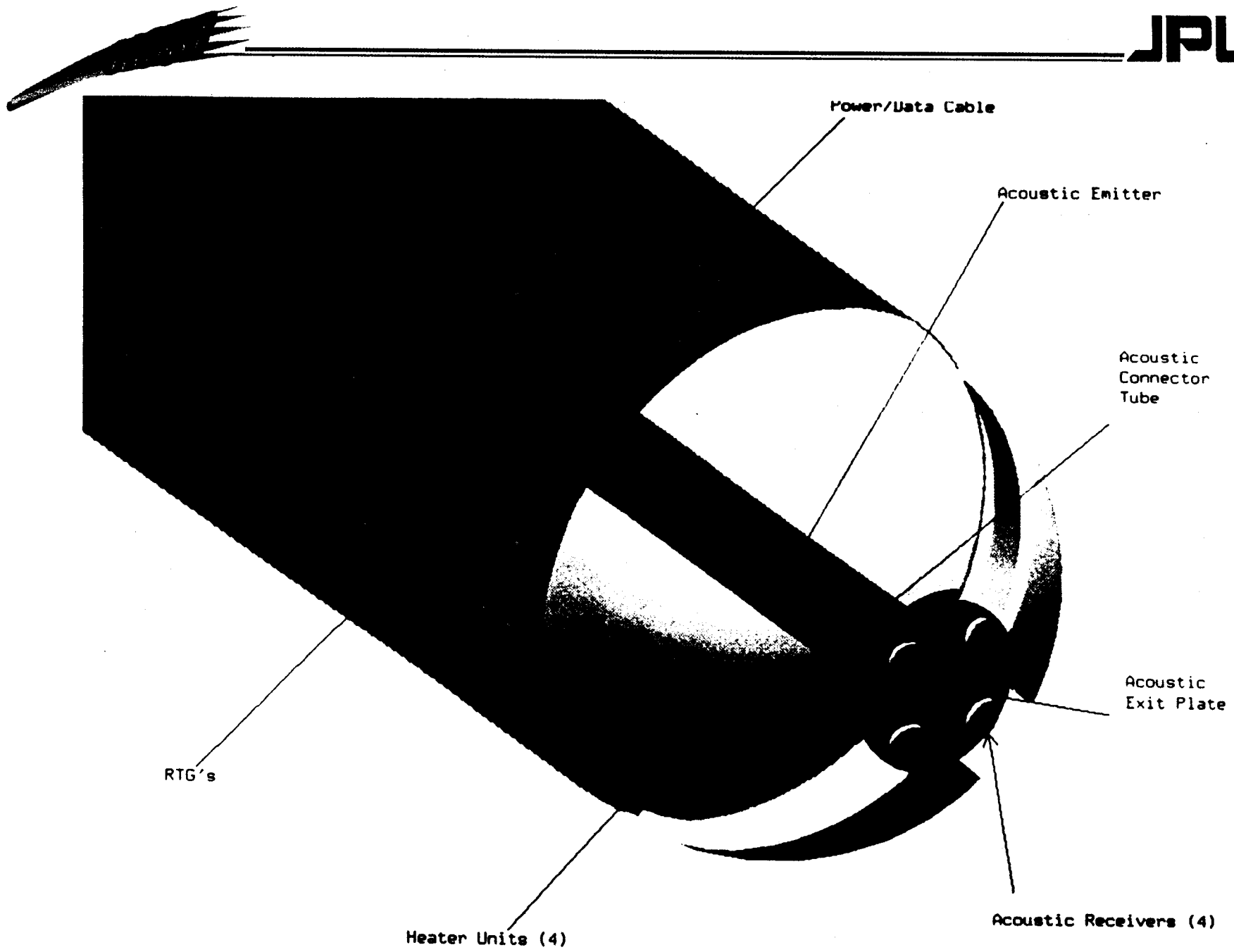
Europa Mole Penetrator

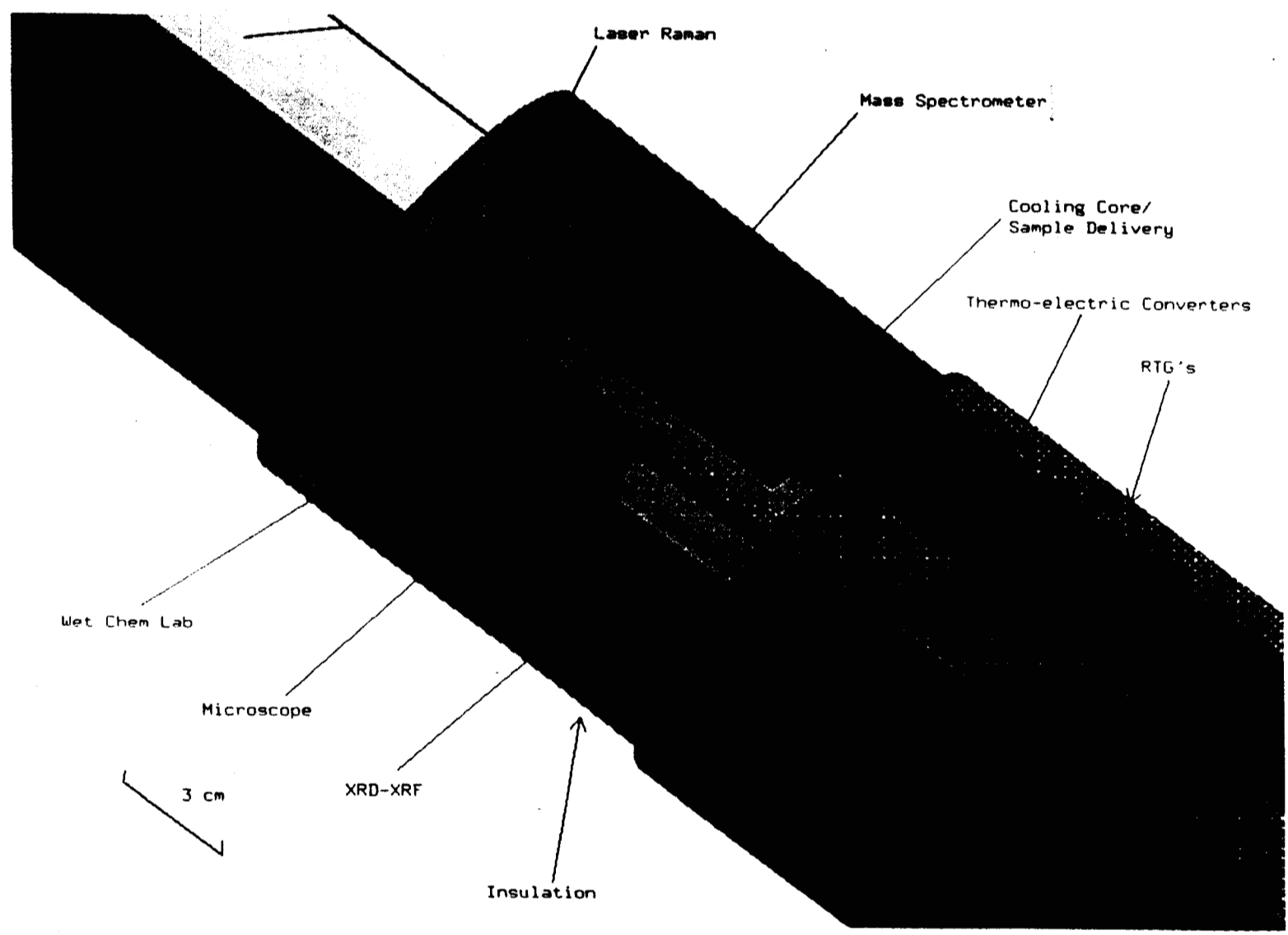


CHIRPS Design (Cont'd)

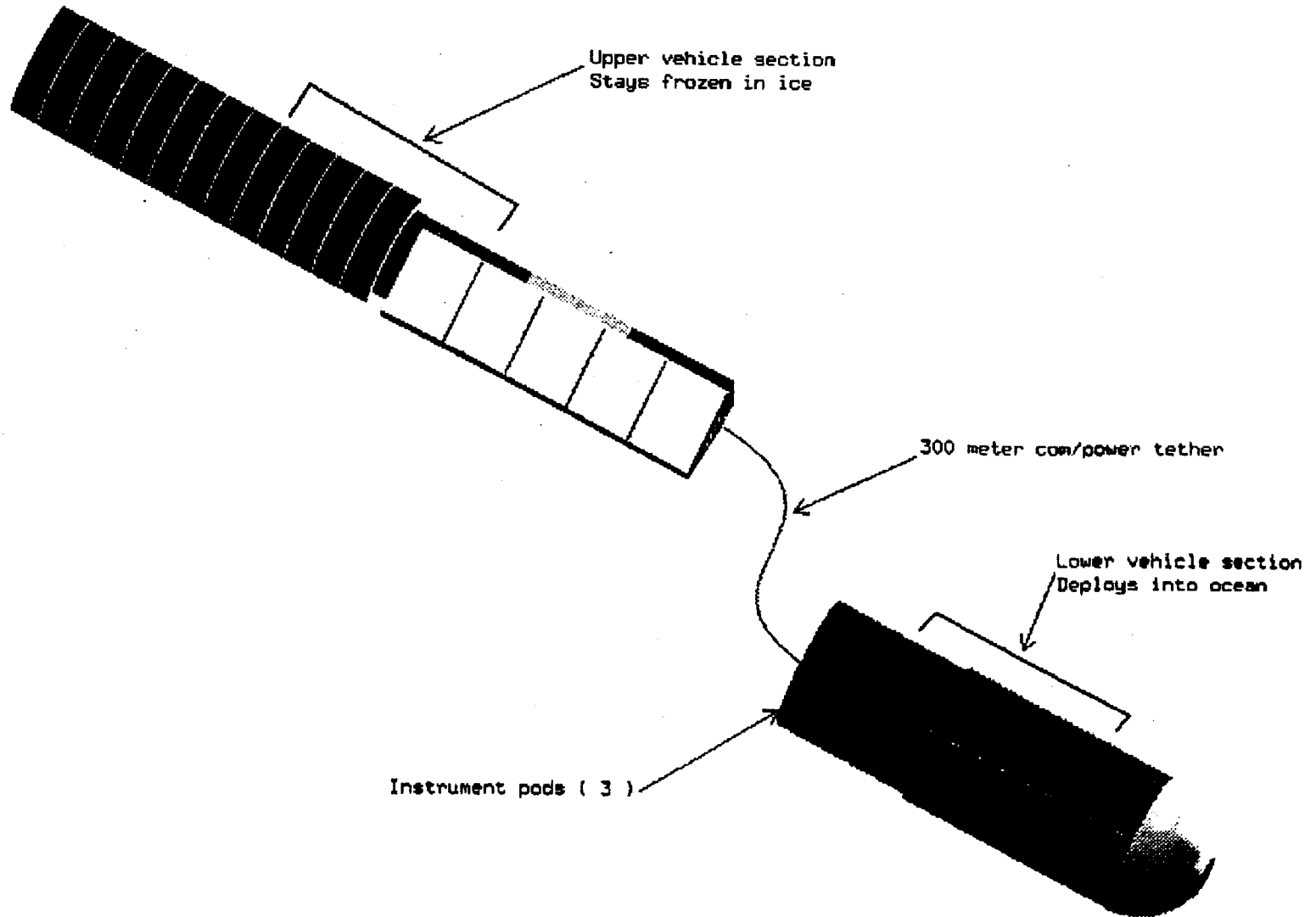
- **Controlled melting/steering provided by capillary fluid loops @ nose, midsection of shell, and rear**
 - Working fluid (ammonia or water)
 - Flow rates (1gm/sec.)
 - Flow control by peristaltic micro pumps
- **Communication transceivers and/or tether mounted at extreme rear of vehicle**
- **Projected vehicle mass-21.45kg (includes structure for vehicle support/insertion)**

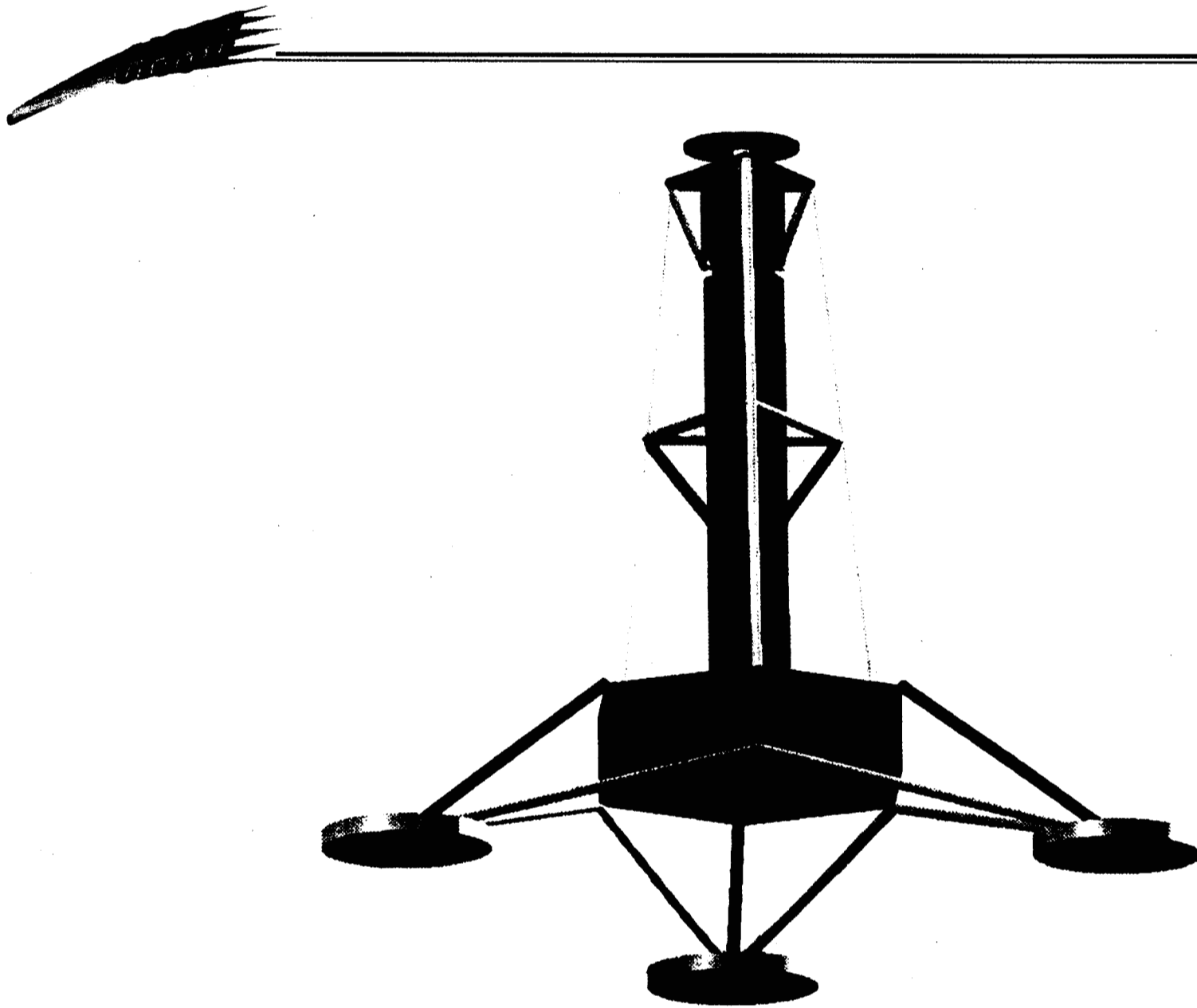
Note: It is understood the instrument suite has not been picked. Therefore, the approach taken was to pick a suite of likely instruments and determine if the complete suite could be placed in the instrument bay. By trying to fit the maximum number of instruments into the vehicle, a conservative mass/volume estimate could be reached. The philosophy behind the selection was that it is easier to reduce mass/volume later rather than add mass/volume.



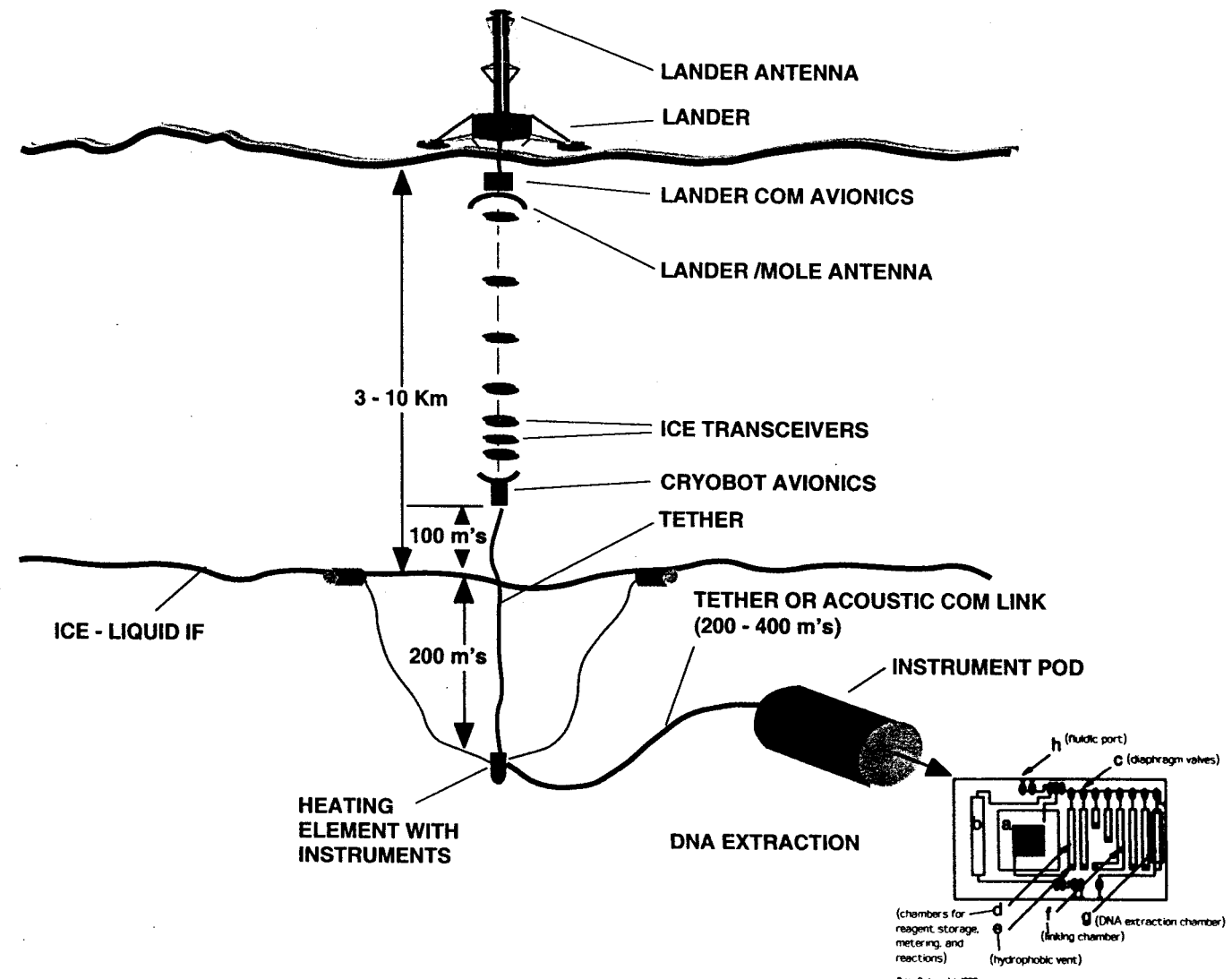


Penetrator with Tether





Cryo-Hydro Integrated Robotic Penetrator System (CHIRPS)



Becca Review July 1999



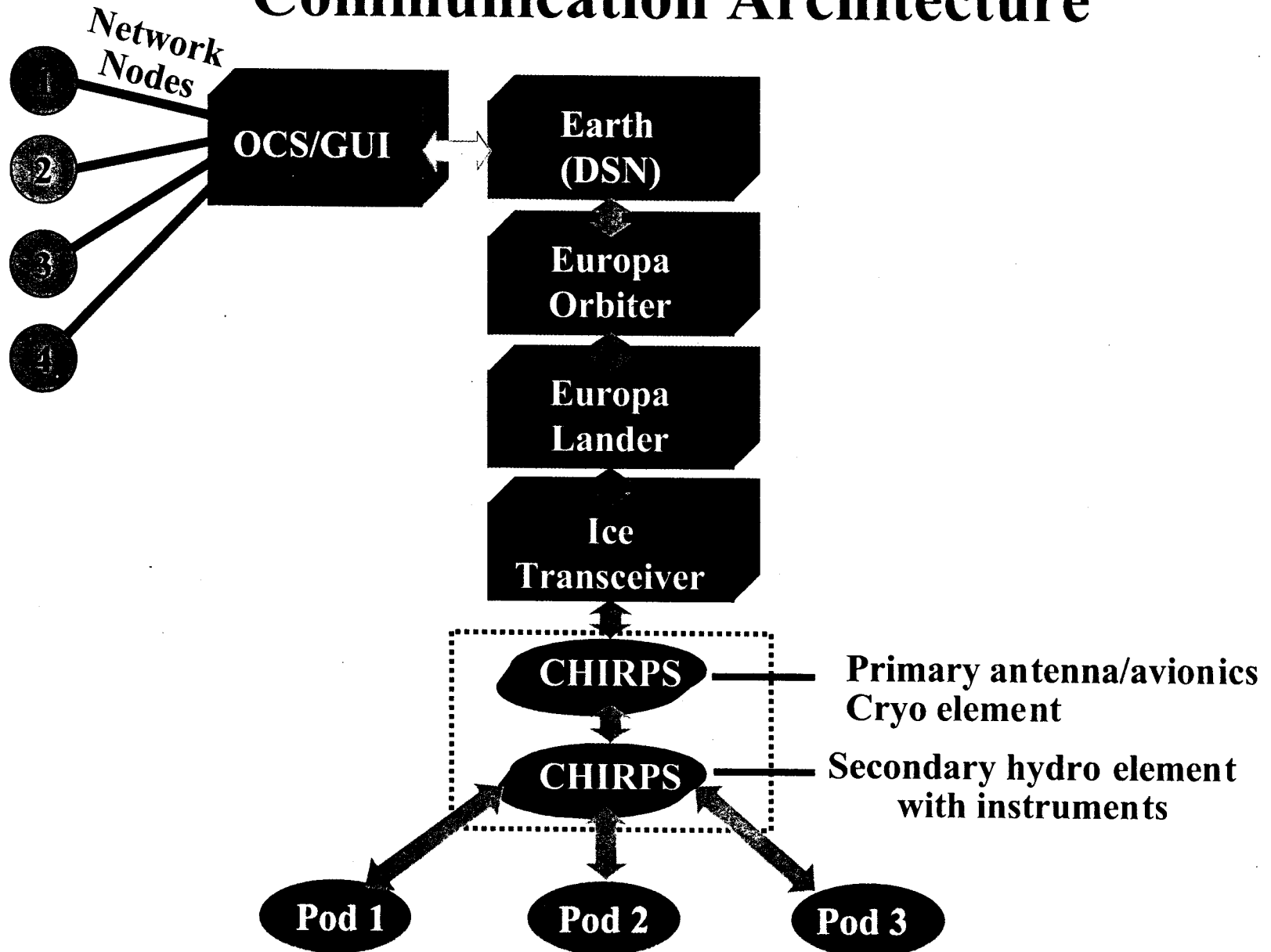
CHIRPS Deployment Sequence

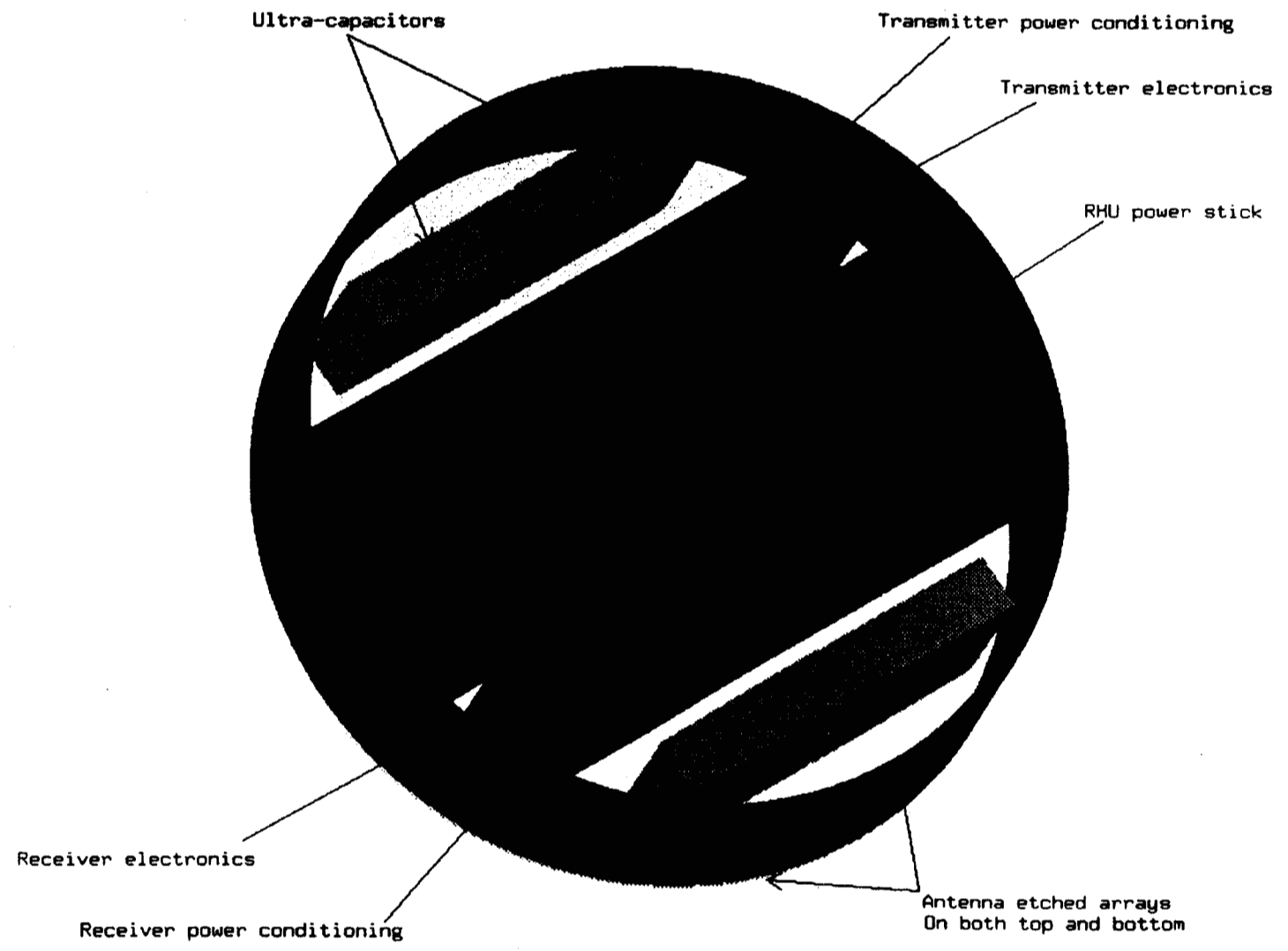
- **CHIRPS and communication electronics are vertical and in stowed/locked position during landing**
- **After touchdown, lander bay doors open under lander and pyros blow launch locks**
- **Telescoping support struts allow vertical alignment for straight probe insertion**
- **As CHIRPS initiates thermal melt control cycle, surface material sublimates creating void in surface ice**
- **Communication electronics module follows CHIRPS into ice and settles in evacuated void where shape memory doughnut inflates and acts as radiation cap/anchor**
 - **Lander antenna stays on surface**
 - **Umbilical between com electronics and lander antenna allows transfer of signal**
 - **Twenty (20)cm dia receiver/transmitter on bottom of antenna electronics module is snapped open before melt region refreezes**
- **As CHIRPS melts through ice, transceiver modules are deposited in meltwater region behind vehicle as function of**
 - **Signal strength**
 - **Distance traveled**
- **Transceivers are deposited in ice using shape memory ejection lever (heat activated)-- upon ejection a spring snaps open in meltwater region (approx. 5m dia) behind vehicle and acts as an anchor in melt hole**

CHIRPS Deployment Sequence (Cont'd)

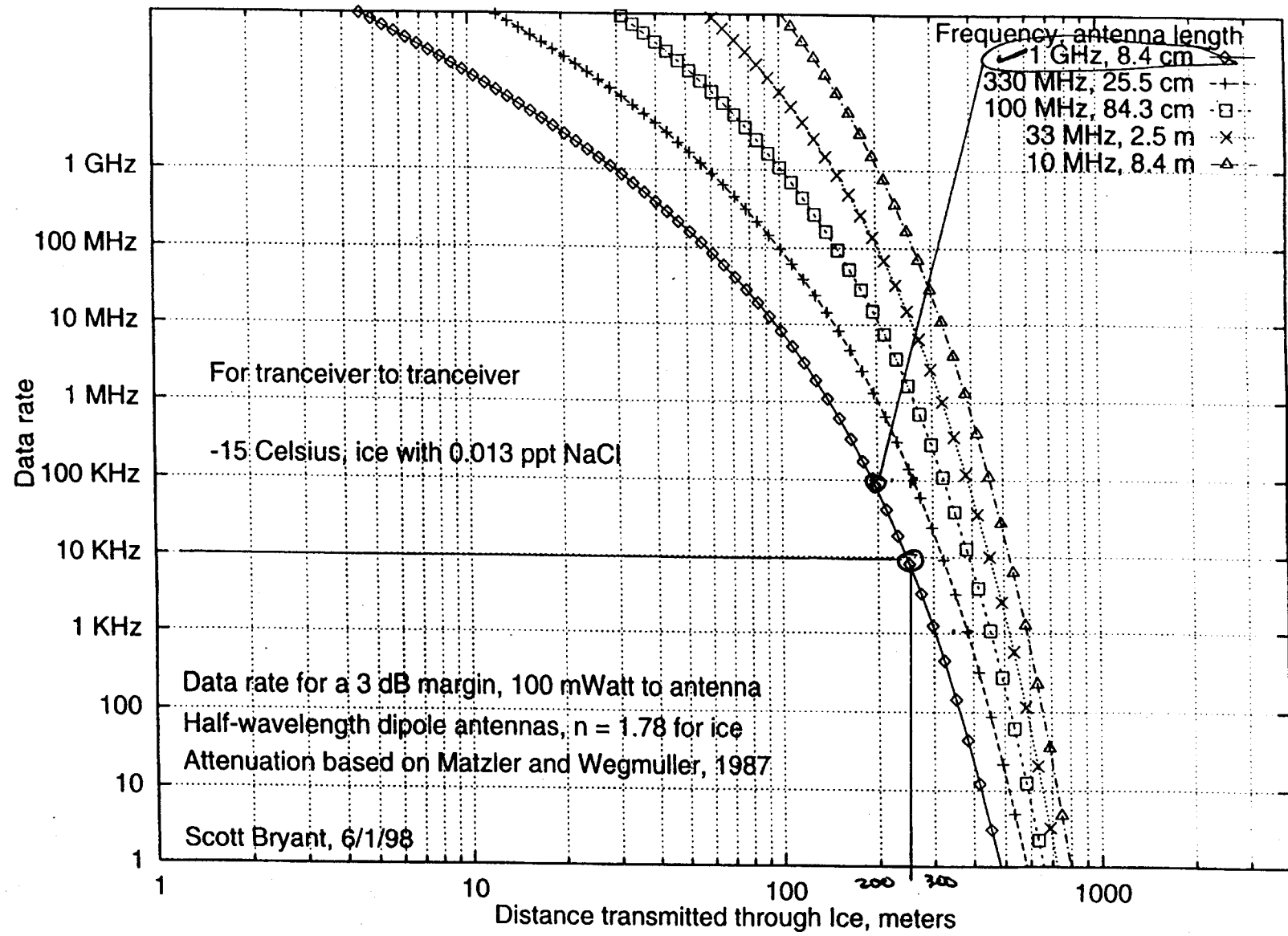
- **Current transceiver design incorporates**
 - **.1m dia quad-dipole etched antenna**
 - **3-lw RHU's for electronic power/internal heating (provide 120mw Electric)**
 - **Ultra-capacitor (chargeable to 1.3w electric to allow data burst power)**
 - **Transmitter/receiver dipole array/electronics**
 - **Databuffers**
 - **Shape memory spring loaded .5m dia anchor to maintain transceiver position in ice**
 - **Nominal data transfer rate-10Kb/sec**
 - **Nominal range between transceivers-300m (assuming ice @ -5degC/high salinity)**
 - **In event ice is > 10km, vehicle would not reach liquid IF but imaging/meltwater sampling would be done until limits of communication system reached**
 - **In event ice is <4km, vehicle would separate @ 100m's above liquid IF**
 - **Electronics bay/antenna would freeze @ 100m mark**
 - **ARPS and instrument bay on 300m tether would continue to melt down, break through ice-liquid IF, and come to rest ~ 200m's below ice-liquid IF**
 - **Small pods containing RHU power source, tether (or acoustic transmitter), and chem-lab on a chip are jettisoned and passively float ice-liquid IF to allow sampling/chemical analysis**

Communication Architecture

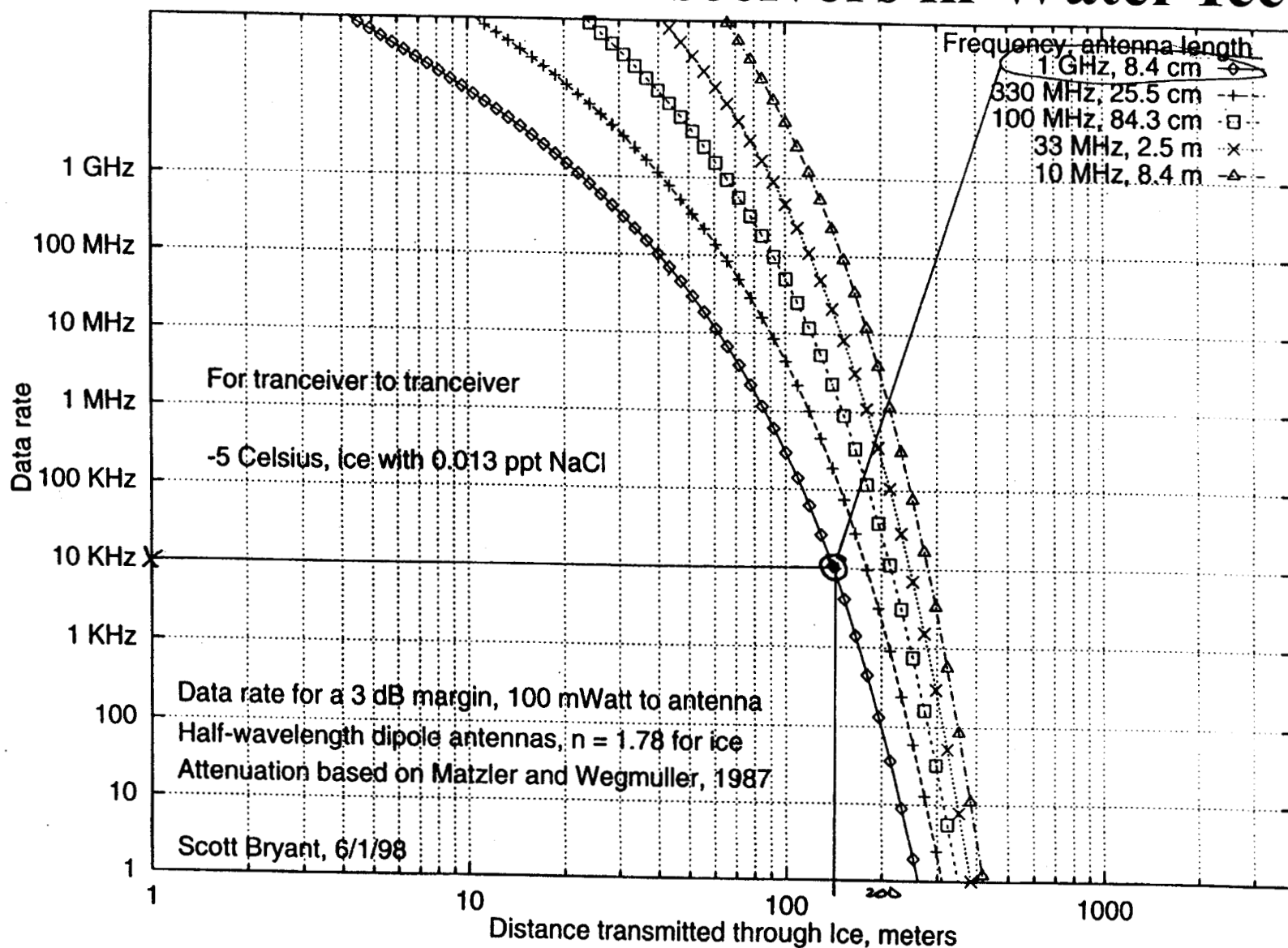




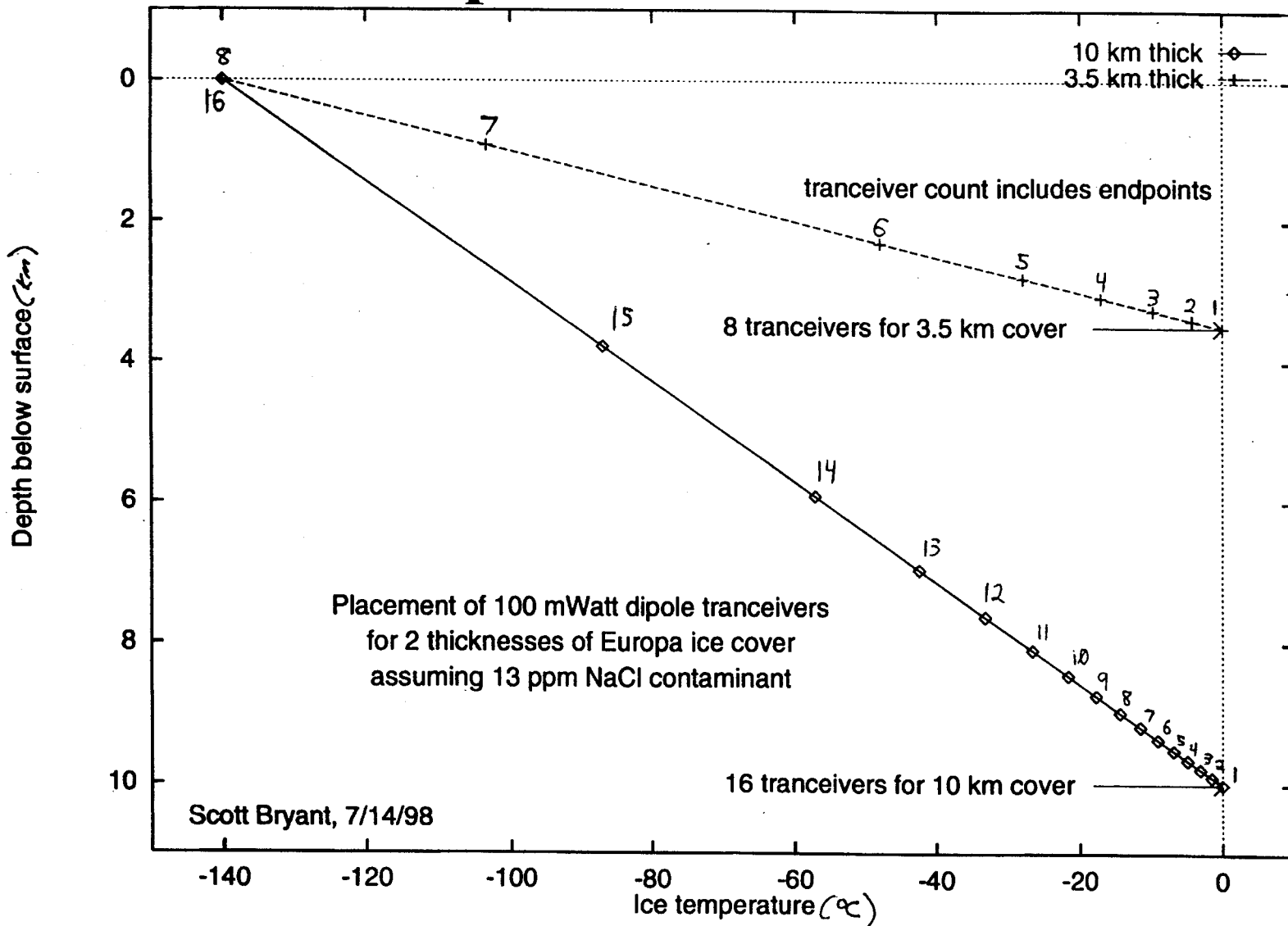
Data Rate for Transceiver in Water Ice



Data Rate for Transceivers in Water Ice



Penetration Depth for 1 GHz Transceiver in Ice





Major CHIRPS Technology Drivers

- **Micro-transceivers for harsh environments-must transmit >300m's in dirty ice**
 - **High frequency (GHz), low power micro -transmitters/receivers (>120 mw transmit power)**
 - **High efficiency/low area micro-transmitter patch arrays and/or dipole arrays (effective antenna size >.5m)**
 - **Low volume, integrated signal buffering/error correction on-a-chip**
- **Transceiver high efficiency, high energy density, low volume power sources >1w**
 - **Obtain conversion efficiency ~>15%**
- **Capillary scale, low power micro-pumps L>1gm/sec)(e.g.,peristaltic pumps)**
- **Electronics for extreme environments (cold/hot) (~<-140°C; >800°C)**
- **Electronics for high rad environments (>20M rad total dose)**
- **High force shape memory alloys (heat or cold activated)**
- **Micro instruments (CISM class chem-lab on-a-chip)**
- **Intelligent vehicle/communication control**
 - **Power management**
 - **Vehicle dynamics**
 - **Communication module release/activation/data management/signal transfer**