Nodule Collector Subsystems-Organizations of the OMI Pilot Mining Test Program and its Use In Collaborative Tests By Contractors

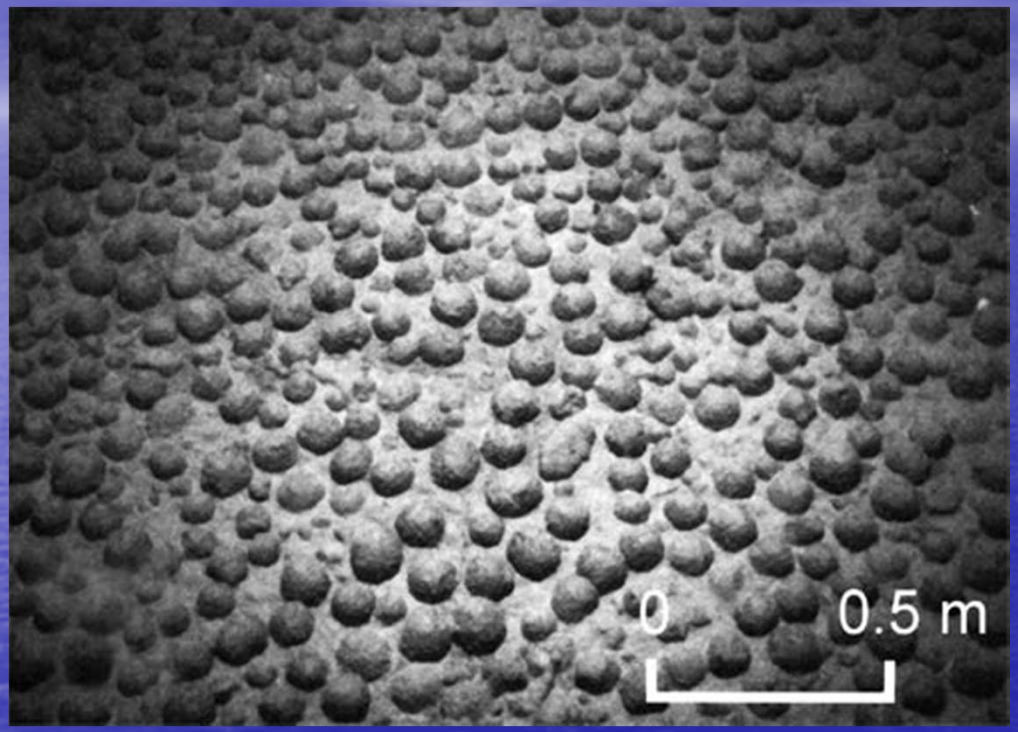
Presented at the ISA Workshop On Polymetallic Nodules Resource Classification

By: Ted Brockett

Background

- Ocean Management Inc. (OMI) Consortium
  - INCO US Inc.
  - AMR
  - DOMCO
  - SEDCO
- Successful Pilot Mining Test 1978
  - CCZ, ~5,400 Meter Water Depth
  - >600 Tons of Nodules Delivered to Surface
  - Culmination of 4-Year Development Program
  - Proved Technical Feasibility of Ocean Mining!

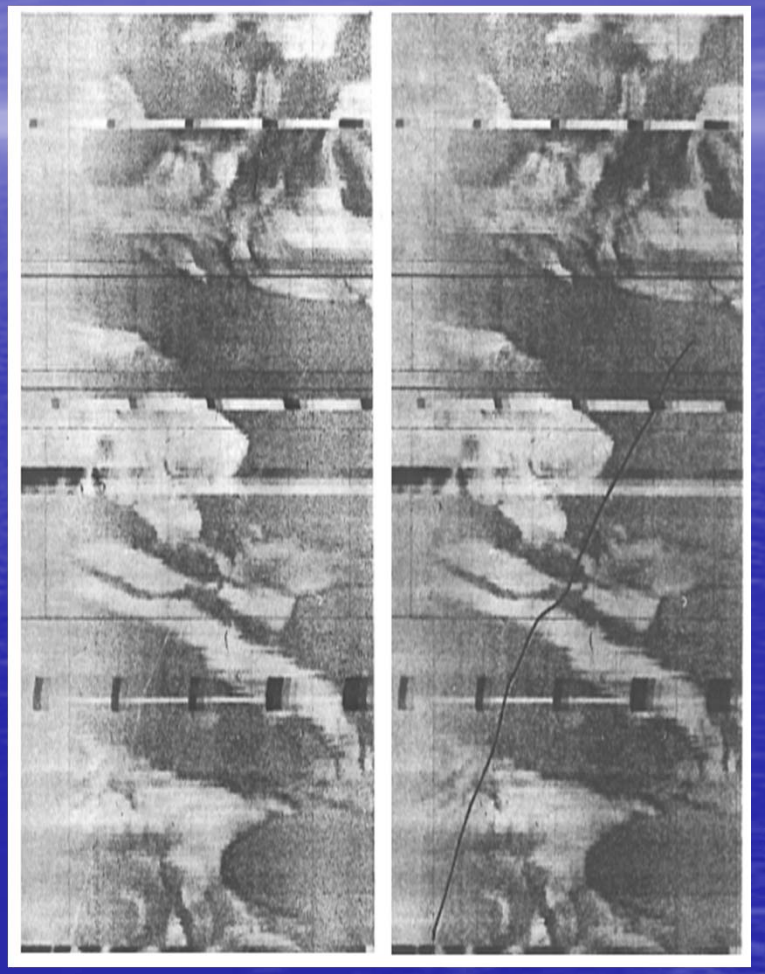
Resource



Nodule density of 2lbs per square foot.

High Speed Exploration System

- HSES Tested In 1977
- Side Scan Sonar Based
- Imagery Changed Thinking
- 165 Sq. Km Surveyed
- Surface Deposit
- Distribution Varies
- Proof Positive
  - Collector Tracks



HSES Image (1977)

OMI Team Approach

- INCO Lead for Collector Development
  - Program Management
  - Hydraulic & Passive Collector Development
  - Land Based Test Facility Design & Construction
  - At Sea Collector Test Program
- DOMCO Assistance Task
  - Hydraulic Collector Development
  - Land & At Sea Test Participation
- AMR Assistance Task
  - Mechanical Collector Development
  - Land and At Sea Test Participation

Two Key Collector Design Parameters

- Nodules Considered a Surface Deposit Only
  - No Consideration of Buried Nodules
- Monte-Carlo Approach to Mining the Mine Site
  - Random Course Selection
  - Opposite of “Mowing the Lawn”
  - No Requirement for Steering or Self-Propelled Design
  - Collectors Were passively Towed

Phased Collector Development

- Conceptual Design*
- Laboratory Testing of Key Concept Components*
- Test Collector Design, Fabrication & Assembly*
- Land Based Collector Testing
- In-Situ Deep Sea Collector Tests
- PMT Collector Design, Fabrication & Assembly
- Pilot Mining Tests (PMT)

* Conducted Simultaneously in Three Countries

Laboratory and Tow Tank Tests

- Nodule Settling Velocity
- Jet Sheet Nozzle Flow
- Inclined Duct/Ramp Flow
- Horizontal Nodule Transport
- Entrainment Ratios
- Hydrodynamic Towing Stability

Land Based “Mud Pit” Tests

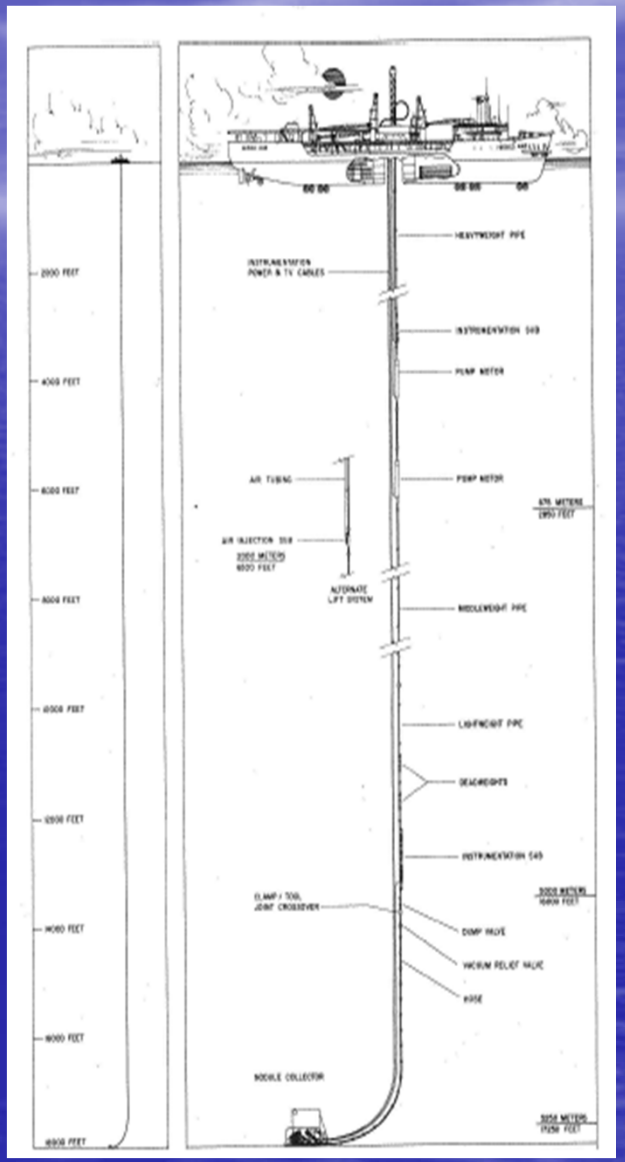
- 200’ x 12’ x 12’
  - Cost Effective
  - Simulated Nodules
  - Simulated Sediment
- Passive Collectors
  - Rhombic Rake
  - Passive Inverted Plow
- Active Collectors
  - Electro-Hydraulic
  - Active Inverted Plow
  - DOMCO Hydraulic
  - CDZ, CDM and CBS Mechanical
- RR, PIP, CDZ Collectors Eliminated

1976 In-Situ Deep Sea Collector Tests

- R/V Valdivia
- CCZ Test Site
- Tow Cable/No Riser
- Collectors Tested
  - Electro Hydraulic & AIP
  - DOMCO Hydraulic
  - Cutter Blade Scraper (CBS)
  - CDM Collector Aboard - Not Tested
- DOMCO & EH Showed Most Promise
- DOMCO Selected as Primary PMT Collector
- CBS Collector also Selected for PMT

1978 Pilot Mining Test

- SEDCO 445
- Submersible Pumps & Air Lift
- CCZ, ~5,400 Meter Water Depth
- 9-5/8” OD Riser Pipe
- Cast Lead Dead Weight(s)
- Dump Valve
- Vacuum Relief Valve
- 8” & 6” Interface Hose
- 2M, 3M or CBS Collector



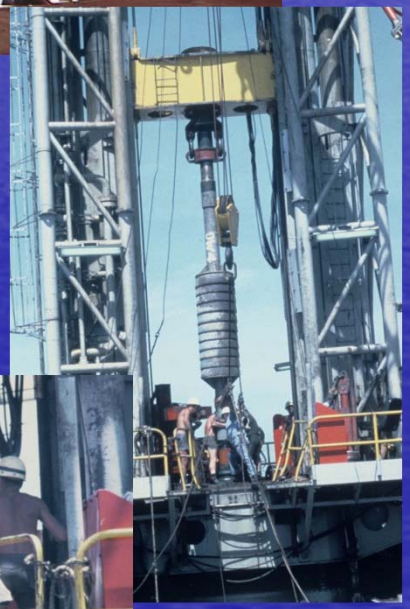
1978 Pilot Mining Tests
SEDCO 445

Submersible Pump and Air Lift Systems

- 1,000 HP KSB Submersible Pumps
- In Line Caisson Design
- Two Pumps for Use with 2M
  - Up to 40 Metric Tons/Hour
- Three Pumps for Use with 3M
  - Up to 60 Metric Tons/Hour
- Air Injection at 2,000 Meters
  - 3,000 psi Compressors
  - For Use with 2M or CBS Collectors

Riser System Components

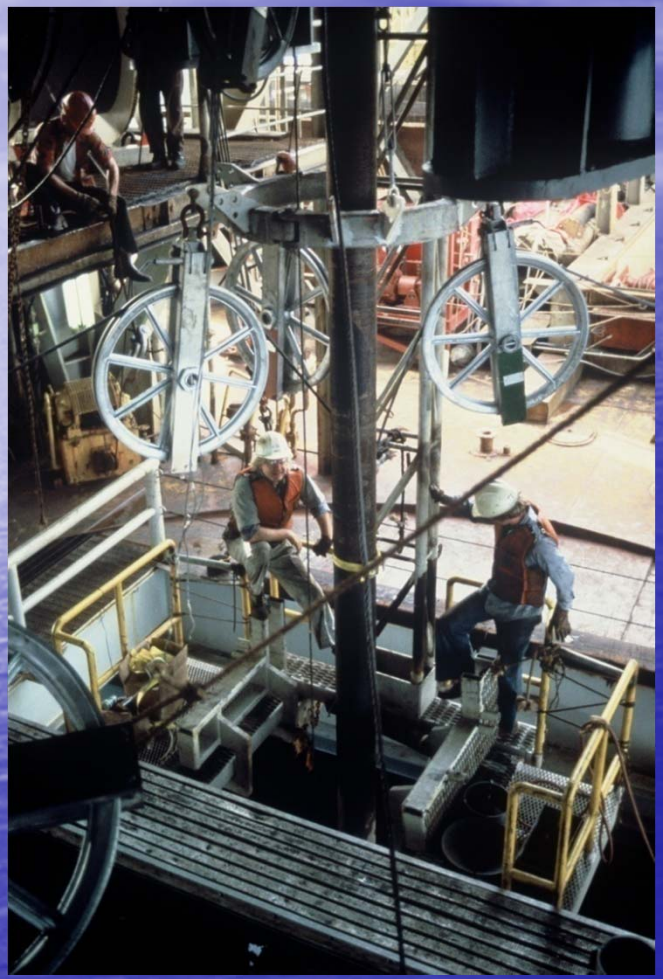
- 5,350 Meter Nominal Length
  - Thick Wall Heavy Weight Upper Section (~900m)
  - Medium Weight Middle Section (~450m)
  - Light Weight Lower Section (~3,960m)
  - High Strength Rotary Tool Joints
- 8,100 kg Dead Weights (Up to 6)
  - Minimize Bending Stress in Riser
- Dump Valve
  - Dump Nodules During Pump Failure
- Vacuum Relief Valve
  - Allow Water Inlet if Collector Clog

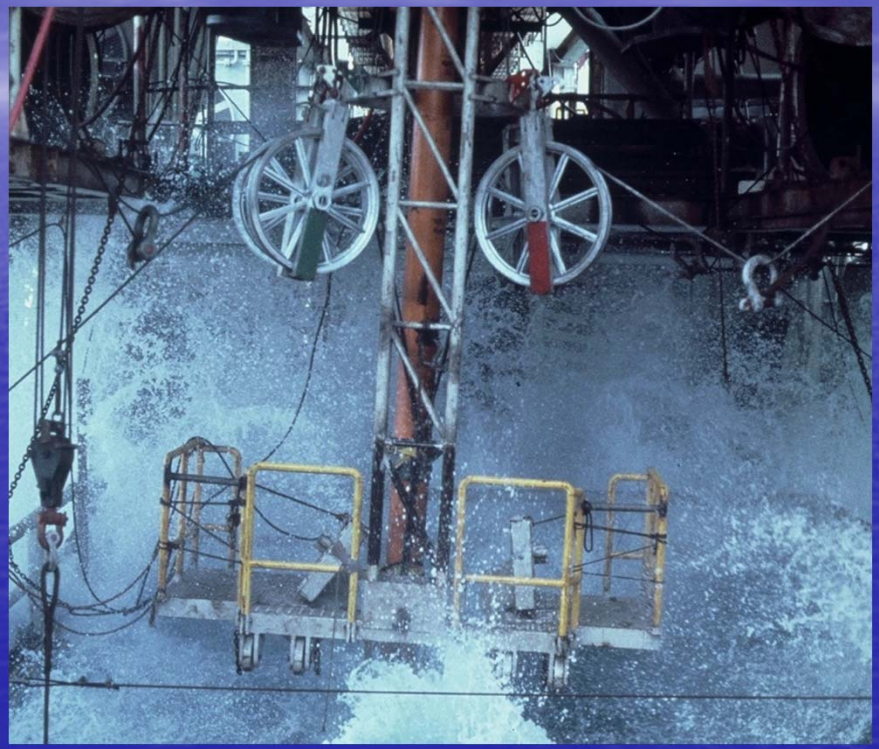


Interface Hose

- 253 Meter Nominal Length
- 8” (203mm) Diameter for Pump Lift
- 6” (153mm) for Air Lift
- 40’ Section Lengths
- Bathymetric Excursions of ±90 Meters
- Unibolt Connectors

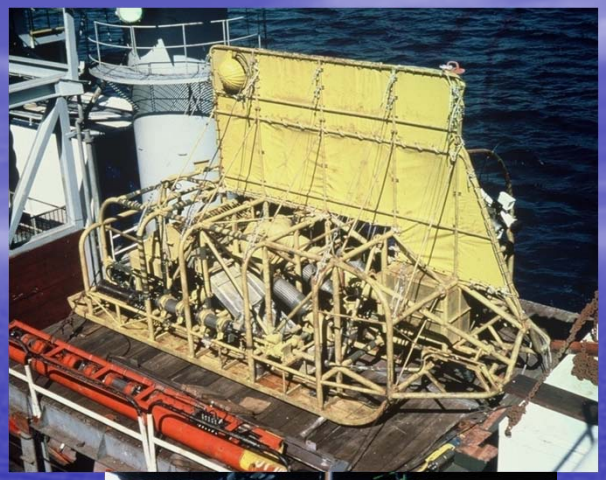
Air/Sea Interface

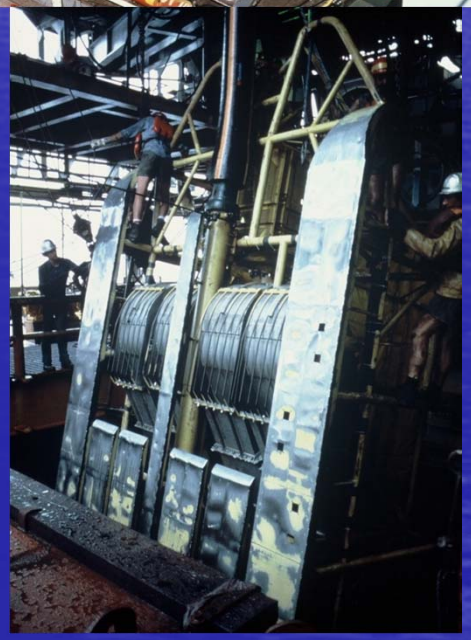




2M Seafloor Collector

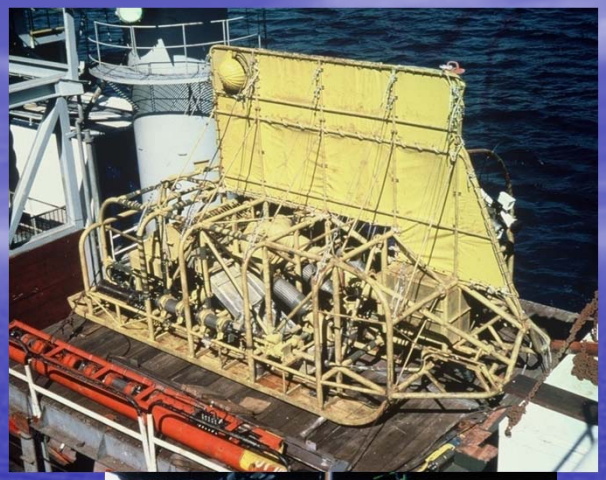
- Passively Towed Two Runner Sled
- Simple Hydraulic Design
  - 20 HP for All Functions
  - Single Ducted Propeller Pump
- 2 Meter Modular Active Width
  - Four ½ Meter Floating Dredge Heads
  - Adjustable Dredge Head Height
- <½ PSI Seafloor Bearing Load Goal
- Cloth Sail
  - Hydrodynamic Stability & Bottom Landing

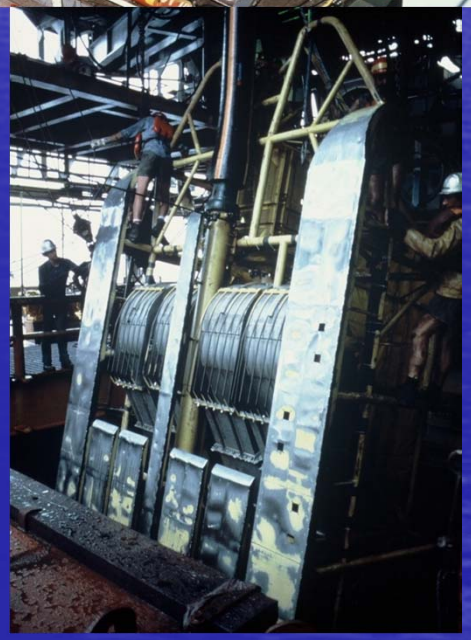




3M Seafloor Collector

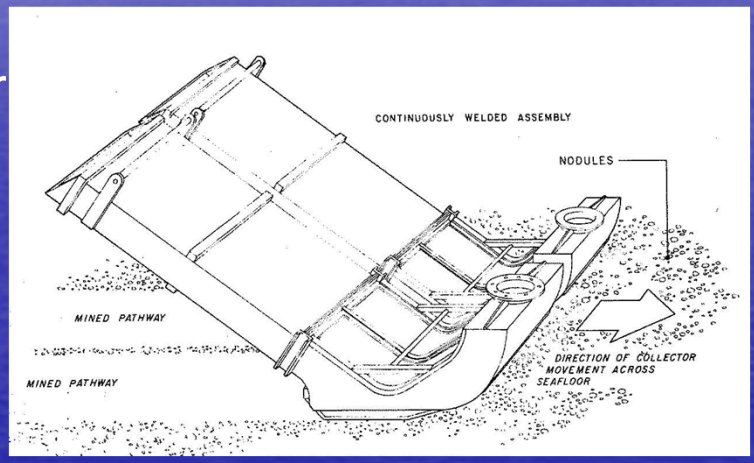
- Passively Towed Two Runner Sled
- Simple Hydraulic Design
  - 25 HP for All Functions
  - Single Axial Flow Pump
- 3 Meter Modular Active Width
  - Six ½ Meter Floating Dredge Heads
  - Adjustable Dredge Head Height
- <½ PSI Seafloor Bearing Load
- Cloth Sail
  - Hydrodynamic Stability and Bottom Landing





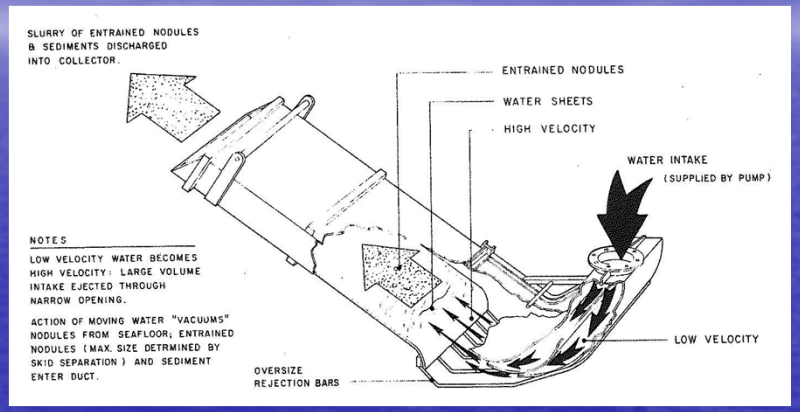
OMI Collector Functional Concept

- Hydraulic Design Uses Only Moving Water for All Work
  - Separation of Nodules from Seafloor
  - Elimination of Sediment
  - Transport of Nodules within Collector
  - Introduction of Nodules into Riser
- Reliability is Key
  - Simplicity = Reliability
    - 1960 US Navy KISS Principle
  - Essentially One Moving Part
- Minimal Wear and Abrasion



OMI Collector Functional Concept (Cont.)

- High Volume Low Pressure Flow
- Jet Sheet Nozzles
  - Flow Follows Curved Surface
  - Scours, Lifts, and Entrains Nodules
  - Nozzles Entrains Added Water
- Transports Nodules Up Duct
  - Turbulent Flow Separates Sediment
  - Raised the Nodules within the Collector

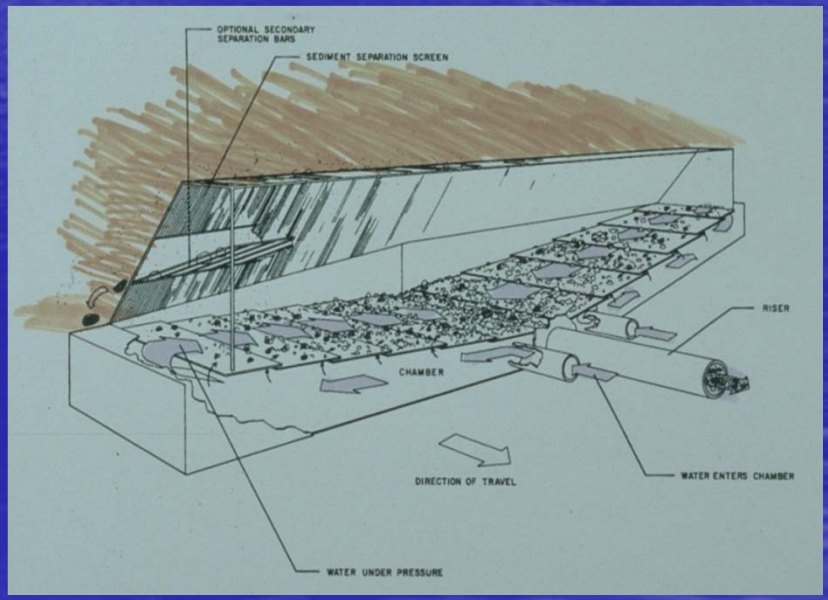


OMI Collector Functional Concept (Oversize Rejection)

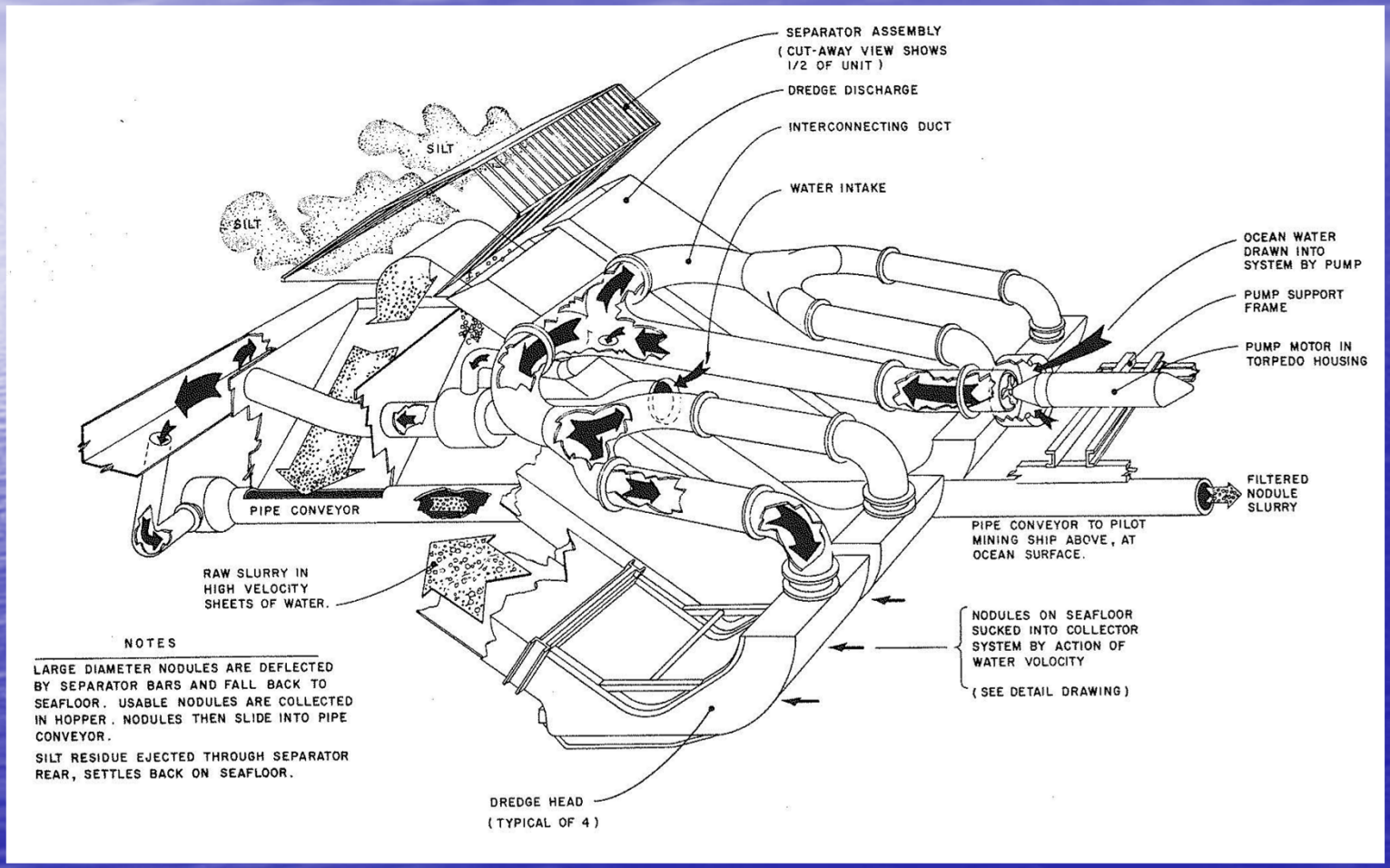
- 2-3/16” Maximum Nodules to Riser
  - Prevent Clogging
- Initial Oversize Rejection
  - Located at Entrance to Dredge Heads
  - Materials Wider Than 3-1/4” Prevented from Entering Dredge Head
  - Collector Forward Movement Passively Cleared Oversize Materials
  - Recognize That Some Materials >3-1/4” Long Could Pass
- Secondary Oversize Rejection
  - Located Behind Discharge of Dredge Heads
  - Materials >2-3/16” Rejected Downward Between Runners
  - Secondary Rejection Powered by Slurry Flow Up Ramp

OMI Collector Functional Concept
(Sediment Rejection & Nodule Containment)

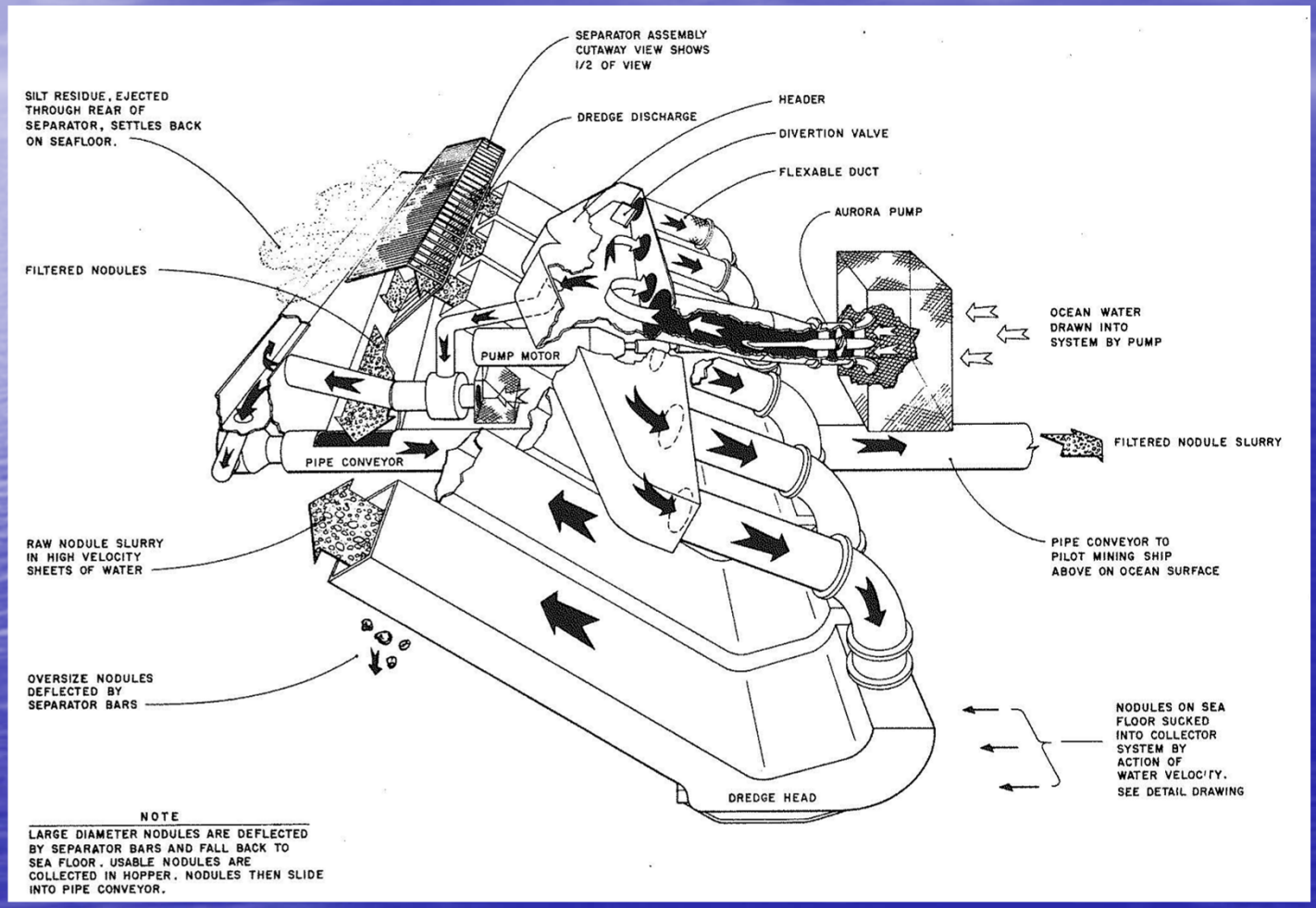
- Cage with Hopper Conveyor
  - 3/8” Openings Retain Nodules & Eliminate Sediment
  - “Dirty” Water Simply Passes Out Thru Cage Openings
  - No Additional Power Required for Sediment Rejection
  - Nodules Transported Using Jet Sheet Nozzles
  - Nodules Fall Into Riser Entrance Duct at Center
  - Riser Suction Entrains Nodules
- Dumps Doors to Clear Jams



OMI Collector Functional Concept (2M Working Fluid Flow)

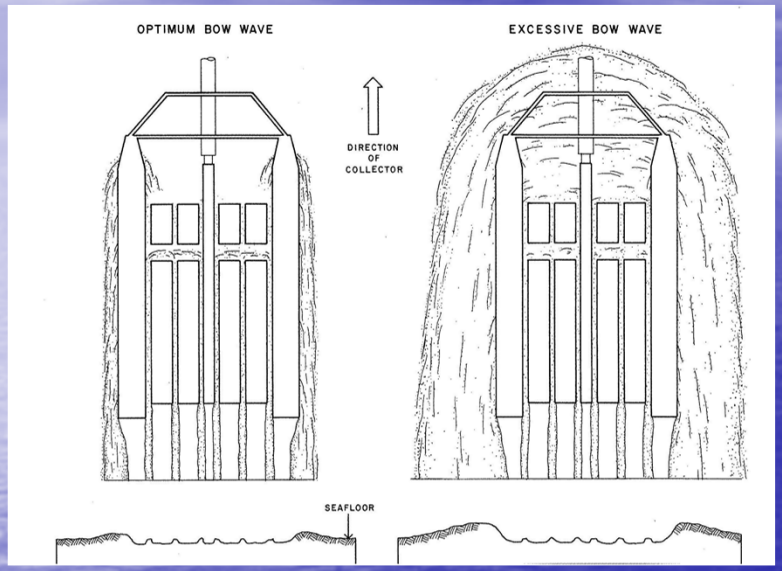


OMI Collector Functional Concept (3M Working Fluid Flow)



Hydraulic Collectors Have Proven Successful Track Record

Bow Waves Can Impact Efficiency



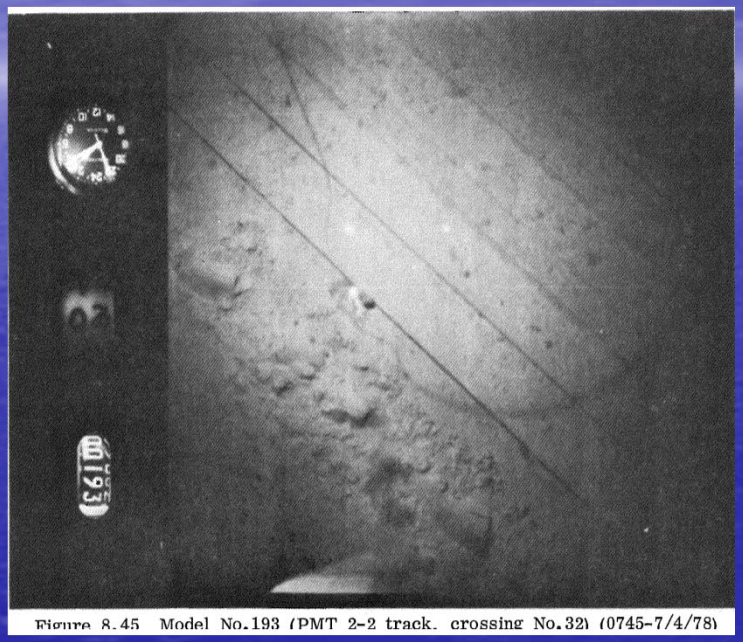


Figure 8.45 Model No.193 (PMT 2-2 track, crossing No.32) (0745-7/4/78)

- Bow Waves Act Like Plows Moving Nodules to the Side
- Bow Waves Reduce Collection Efficiency

Remember KISS

- OMI Hydraulic Collectors Embodied the KISS Principle
  - Used Seawater to Perform All Collector Tasks
  - Required Minimum Horsepower (~10 HP/Meter Width)
  - Simple Reliable Design with Only One Moving Part
  - Moving Part Not in Contact with Nodules or Sediment
  - Proper Bottom Landing Assured By Simple Sail
- Good Collection Efficiency (When No Bow Waves Existed)
- Sediment Rejection at Seafloor w/o Added Power Needed
- Minimum Sediment Transported to Surface (<1% of Flow)
- Collector Bearing Load on Seafloor ~.5 psi or Less
- Passive Oversized Rejection

Opportunities for Improvement

- More Reliable Submersible Motors (Pumps)
- Redundant Critical Components – Motors/Pumps
- Improve Active Width to Equal Overall Collector Width
- Design to Eliminate Bow Waves
- Reduce Bearing Load on Seafloor to Minimize Penetration
- Improve Sediment Rejection Even Further
- Consider Steerable Collector for “Mowing the Lawn”
- Use Current State of the Art Command, Control and Monitoring System

Conclusions

- OMI Conducted Phased Collector Development Program
- Simple, Logical Phases Designed to Maximize Success
- Culminated in Successful PMT with >600 Tons of Nodules Delivered to Ship
- OMI Believed In and Followed the KISS Principle
- OMI Favored and Proved Hydraulic Collectors Work Well
- OMI Proved the Technical Feasibility of Ocean Mining
- OMI Considered Nodules a Surface Only Deposit
- OMI Found Long Term Collector Reliability Is Crucial
- **Be Prepared to Lose Equipment!!!**
- Have Contingency Plans & Equipment in Place

THANK YOU!

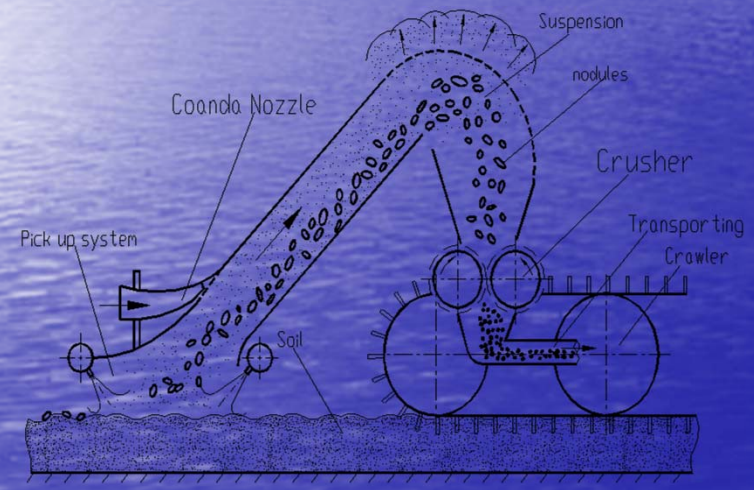
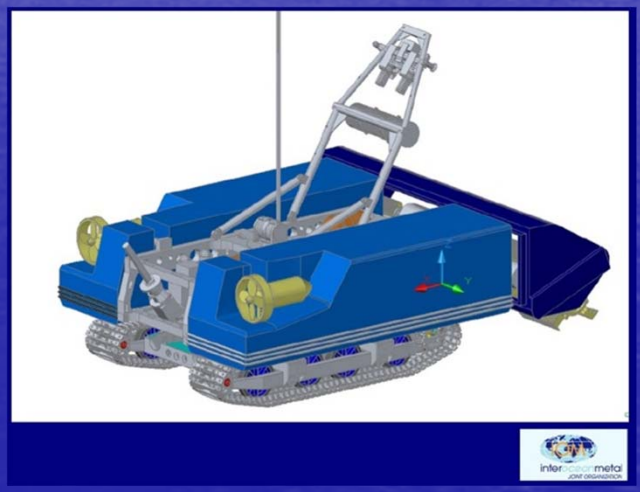


Fig.2 CRIMM's Hybrid Pick-up device



Benthic Impact Experiments

- Benthic Disturber with Many OMI Collector Features
  - –Simple Hydraulic Design
  - –Two Runner Sled
  - –Vertical Sail for Towing Stability
  - –Low Horsepower
- Used During Benthic Experiments
  - – NOAA - 1993
  - – Metal Mining Agency of Japan - 1994
  - – Interocean Metals - 1995
  - – NIO of India - 1997