EAGE

2026 EAGE ANNUAL
87TH CONFERENCE & EXHIBITION
ABERDEEN | UK

Enabling larger-scale onshore seismic with nodes

T. O'Toole, N. Goujon, K. O'Connell, B. Coil, M. Tascher and C. Vasile

Motivation

- Demand for dense, single sensor recording, higher definition seismic imaging, is driving channel count up
- Cable telemetry systems are reaching technical and operational capability limit at ~200K channels (~10K daily roll)
- Nodes have transformed acquisition in most markets and are increasingly being specified for large-scale, high productivity land seismic crews
- Largest nodal crew today: 165K channels, 13K daily node cycle rate

What is required on the receiver system side to enable routine nodal acquisition at this scale?

Analytical Framework: Theory of Constraints

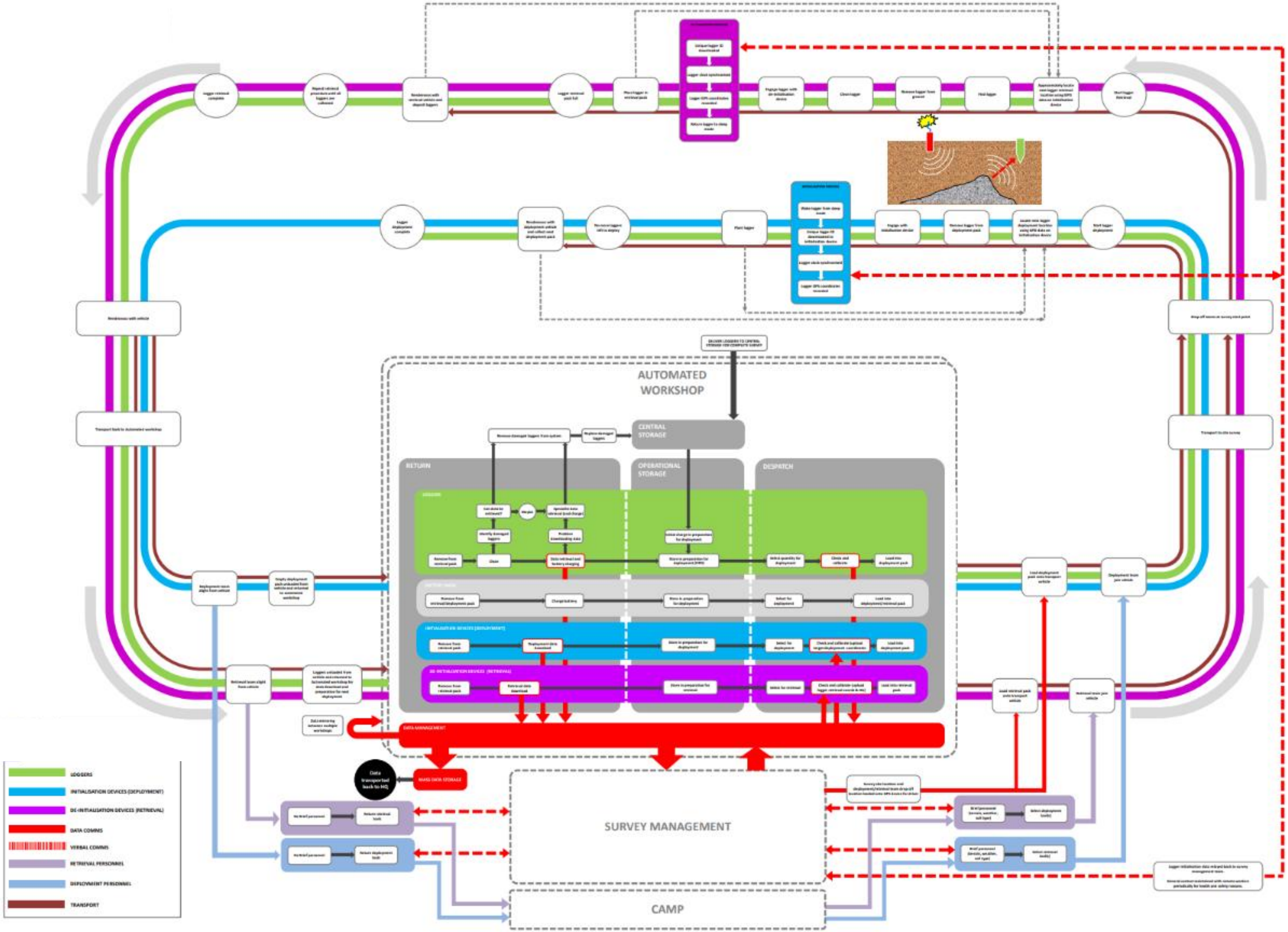
Consider seismic production as a manufacturing process

- Inputs: source and receiver systems, labour
- Finished goods: seismic deliverables to processing

Theory of Constraints (Goldratt & Cox, 1984): systems-based approach to identifying and managing bottlenecks to improve a system. Key concepts:

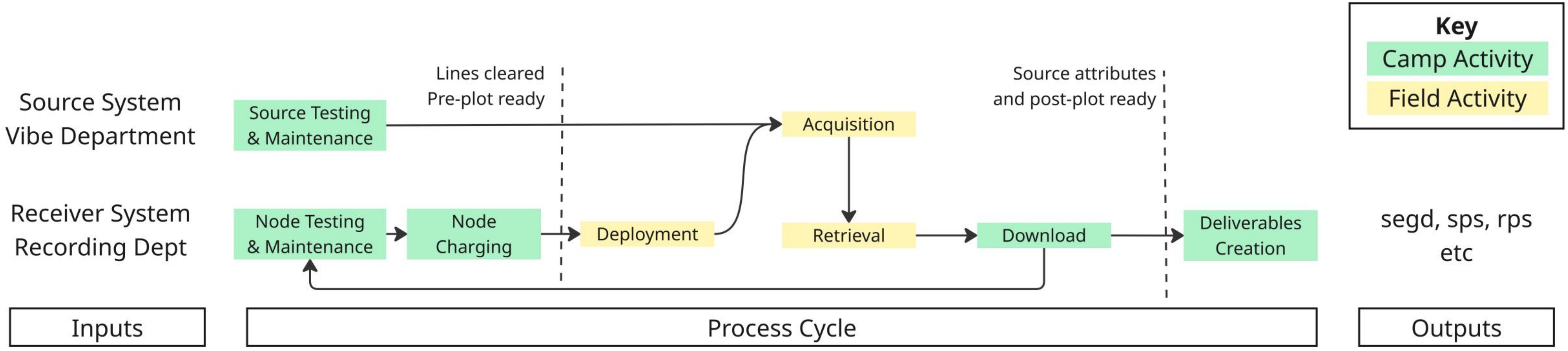
- **Throughput:** value generated per unit time — daily production of QC'd seismic delivered to processing
- **Investment:** recording system hardware, camp, vehicles…
- **Operational expenditure:** crew, fuel, catering…

Identify and elevate the binding constraint to increase throughput while simultaneously reducing investment and operational expenditure



AUTOMATED
WORKSHOP
CENTRAL
STORAGE
RETURN
OPERATIONAL
STORAGE
DESPATCH
DATA MANAGEMENT
MASS DATA STORAGE
Data
transported
back to HQ
SURVEY MANAGEMENT
CAMP
LOGGERS
INITIALISATION DEVICES (DEPLOYMENT)
DE-INITIALISATION DEVICES (RETRIEVAL)
DATA COMMS
VERBAL COMMS
RETRIEVAL PERSONNEL
DEPLOYMENT PERSONNEL
TRANSPORT

Seismic Production Process Map (Simplified)



For vibroseis operations:

- receiver-side productivity controls steady-state production
- binding constraint can temporarily move to source (e.g. weather-related downtime)

Constraints on System Throughput

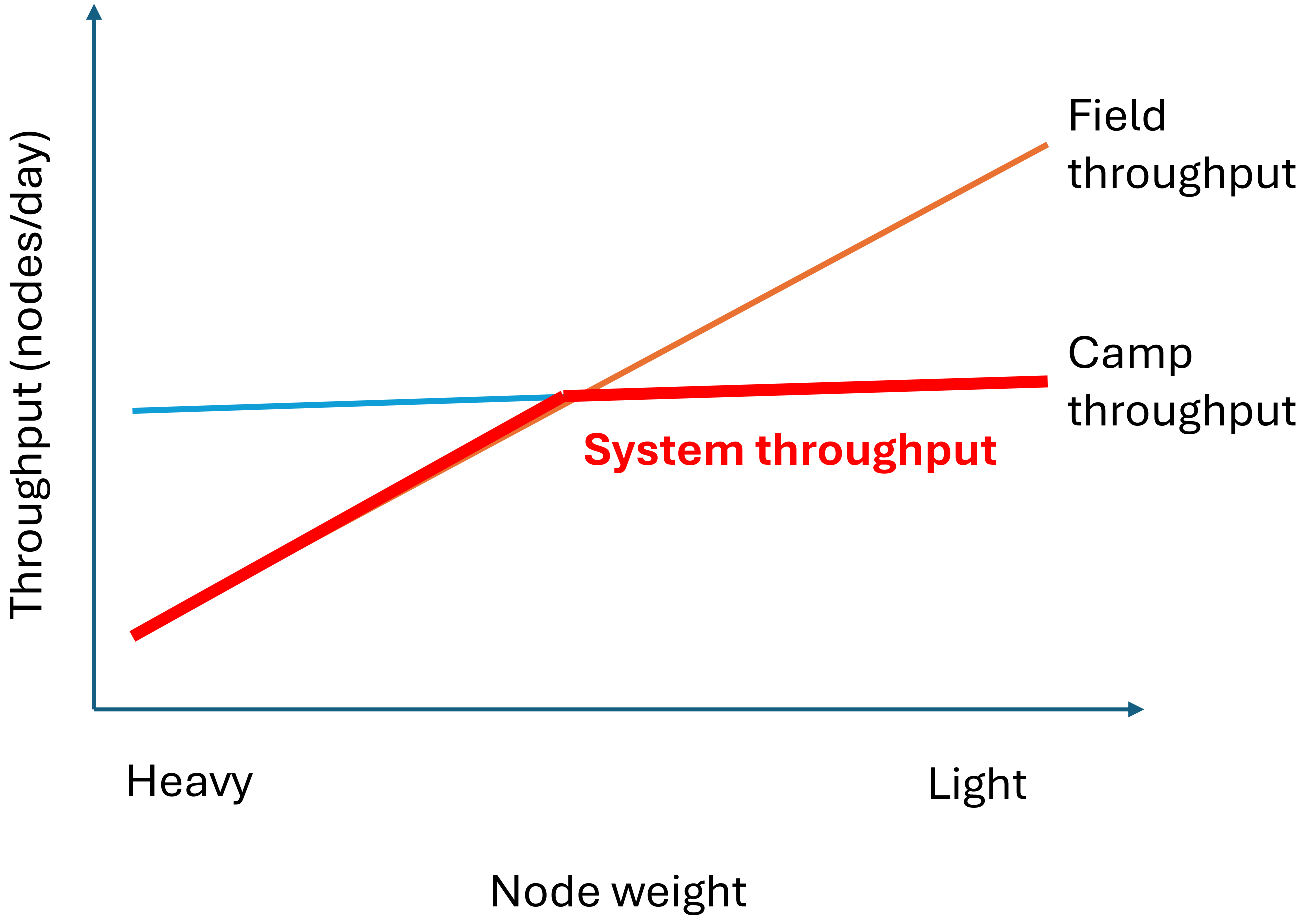
In-field logistics is the binding constraint on field-operations efficiency

- Equipment weight/volume determines vehicle type/quantity and team size
- Equipment size/form factor control deployment cycle time

Reducing node size/weight

- increases field throughput (faster layout = more RPs deployed per day per person)
- slightly increases camp throughput (faster layout/retrieval = shorter recording duration, faster charge/harvesting)
- reduces investment (fewer vehicles)
- reduces operating expense (fewer drivers, lower fuel consumption etc.)

Charge/download rack throughput is the binding constraint on camp-operations efficiency, which is controlled by total rack capacity



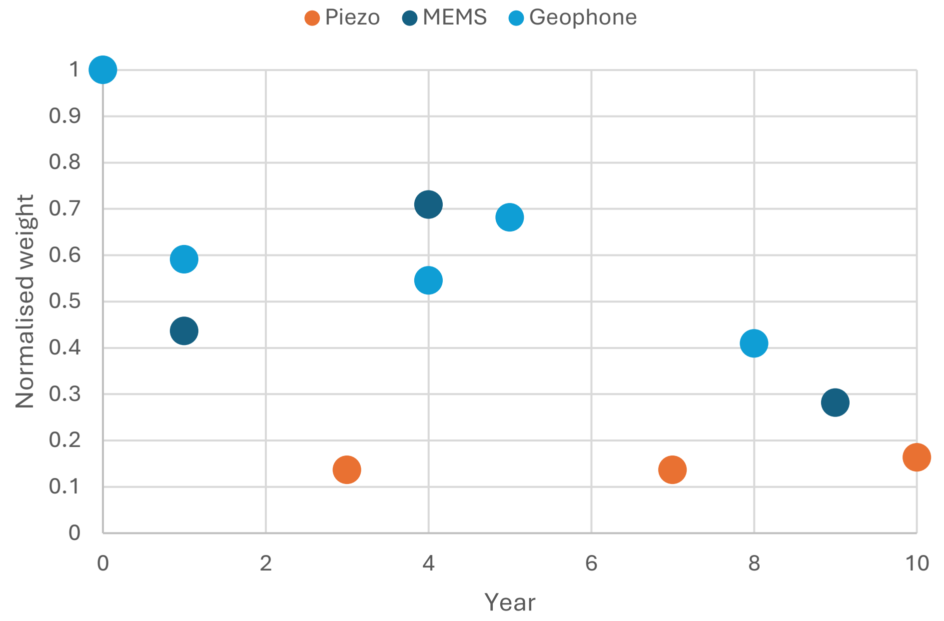
Field Efficiency: Node Miniaturization

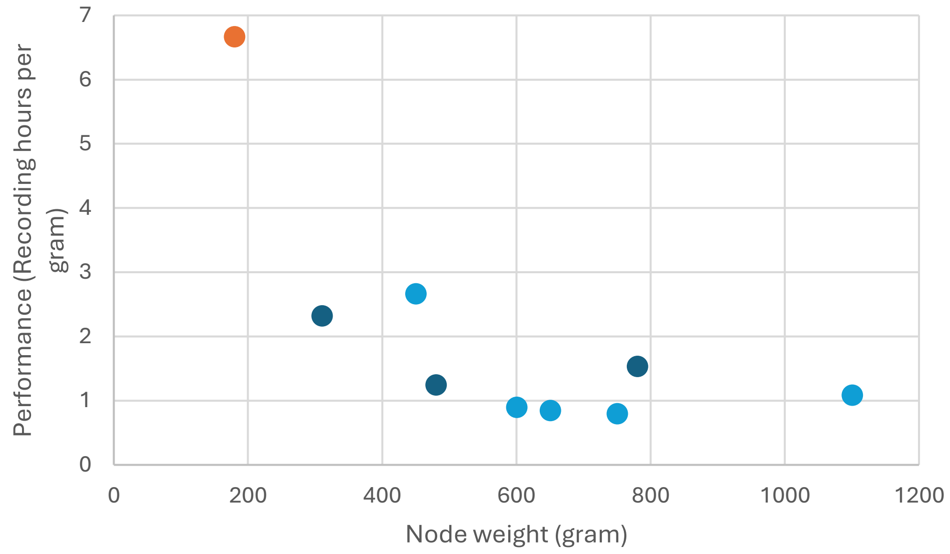
Ideal node: performant sensor and electronics, minimum size/weight/cost, adequate autonomy, easy to bury

Sensor choice controls node size/weight

- Geophone: element constrains minimum node size/weight
- MEMS: very small and light sensor but power-hungry → node size/weight similar to geophone node
- Piezo: battery cell controls form factor/size/weight → overall smallest form factor and lightest node

- Trend is for smaller and lighter nodes
- Further improvement in MEMS and geophone node size/weight challenging without trade-off vs autonomy





Field Efficiency: Node Burial

Full burial

- Best data quality (coupling, verticality, surface noise attenuation)
- Eliminates surface obstruction → unconstrained vibrator navigation
- Reduces theft and equipment damage → maximizes trace recovery, minimizes equipment replacement costs

Form factor controls deployment speed

- Compact, tapered form factor → feasible to bury all sensors, quickly in most ground conditions

Terrain	RP Increment	Cycle Time	RP per hour
Flat desert	8.33 m	11 s	327
Flat desert	12.5 m	13 s	276
Rocky desert w offsets	7.5 m	15 s	240
Flat, hard, gravel	25 m	16 s	225
Dunes	25 m	25 s	144

Average cycle times achieved with ultra-lightweight node across multiple large-scale projects

Camp Efficiency: Charge/Download

Ideal rack is high-capacity, simultaneous charge/download, small footprint, fast to load/unload, modular, redundant

Battery charging is the rate-limiting step

- Charging is slower than data offload
- Charging/download rack capacity governs throughput

End-member rack architectures

- Type 1: batch handling of 90 nodes using motorized lifting aid, simultaneous charge/download
- Type 2: individual manual handling of nodes, combined charge/download
- Type 3: individual manual handling of nodes, separate charging and download hardware

Handling Method	Charging & Download	Rack Capacity & Throughput	Racks	Handling Operations
Batch, motorized	Combined	540 nodes 3,240 nodes/day	4 racks 3 linear m	223
Individual, manual	Combined	36–108 nodes 144–432 nodes/day	35–70 racks 14–42 linear m	20,000
Individual, manual	Separate	32–48 nodes 220–355 nodes/day	56–90 racks 70–120 linear m	40,000

Synthesis

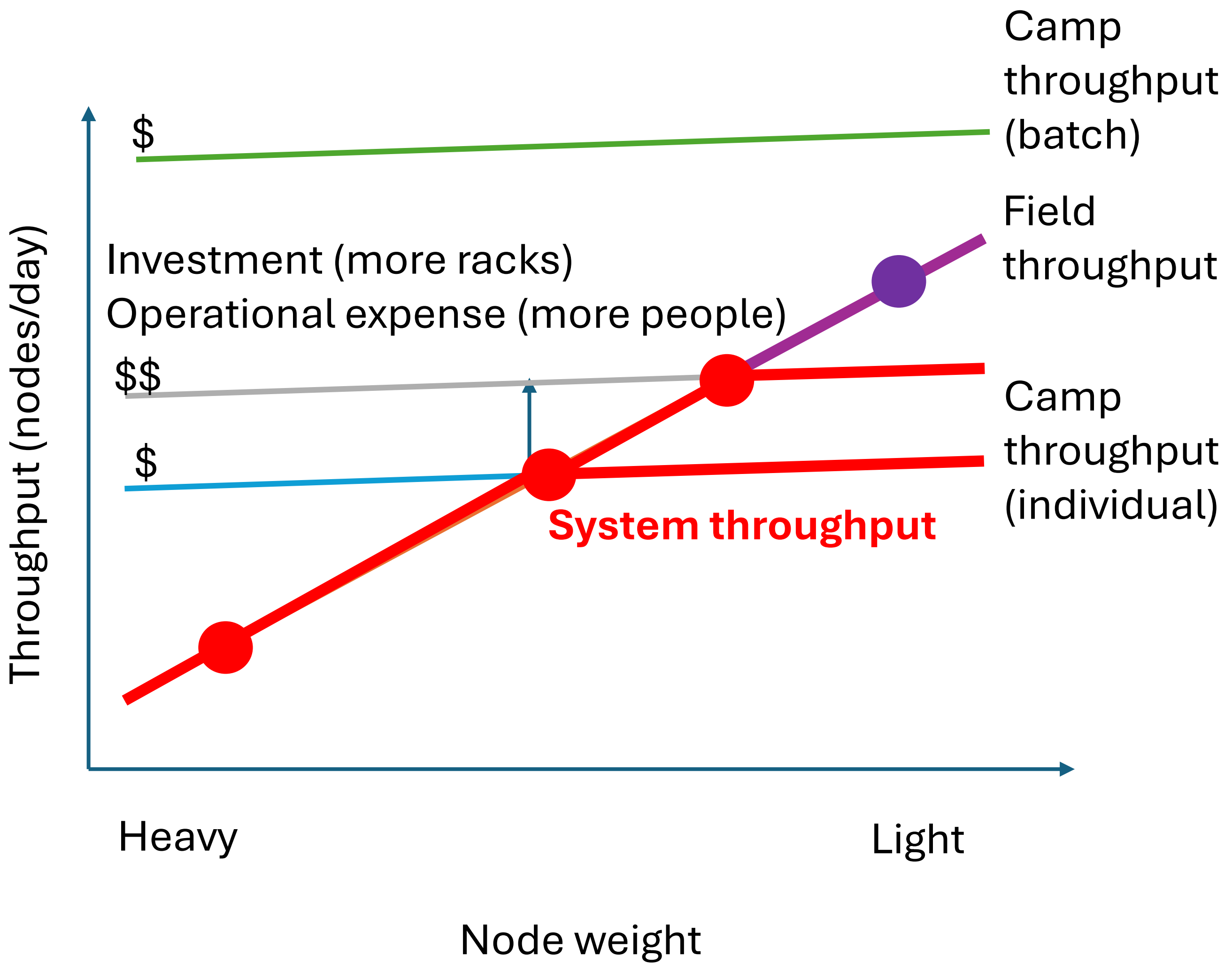
- As nodes get lighter, field throughput rises
- Camp throughput is largely independent of node weight and is controlled by charge/download rack capacity
- System throughput = minimum of the two

Node miniaturization + individual manual handling in camp:

- System throughput constraint shifts to camp
- Increased investment and operational expense is required to improve throughput

Node miniaturization + high-capacity modular batch handling:

- Camp equipment can be right-sized to balance field throughput to minimize investment required to achieve given system throughput
- Preference for spare capacity in camp to accommodate demand peaks (mod, de-mob) and provide redundancy



Conclusions

1. **The constraint on large-scale nodal seismic lies in the camp, not the field**

- Miniaturisation alone migrates the bottleneck from field to camp
- Node and camp hardware are inter-related. They must be designed together, holistically

2. **Individual manual handling cannot scale practically: 20,000+ daily handling operations in camp at 10,000 nodes/day**

- Investment (racks) and operational expense (headcount) scale linearly with channel count and roll-rate

3. **Scalability must be designed in from the outset and cannot be retrofitted**

- Batch motorized handling achieves the same daily roll with 223 handling operations and 3 linear m of racks
- Proven at very large scale: 165,000 channels, 10,000+ daily roll, minimal camp crew

4. **Nodal systems are ready to eclipse the largest cabled system channel counts**

- True scalability has been demonstrated in practice