Development of an acoustic self-locating system for gear marking

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Outline

- Overview of three gear location methods:
    1. Surface GPS
    2. Ranging (also known as surveying)
    3. Successive acoustic receive time (SART) localization
- Development of SART localization, including preliminary field trials
- Pros and cons of gear location methods

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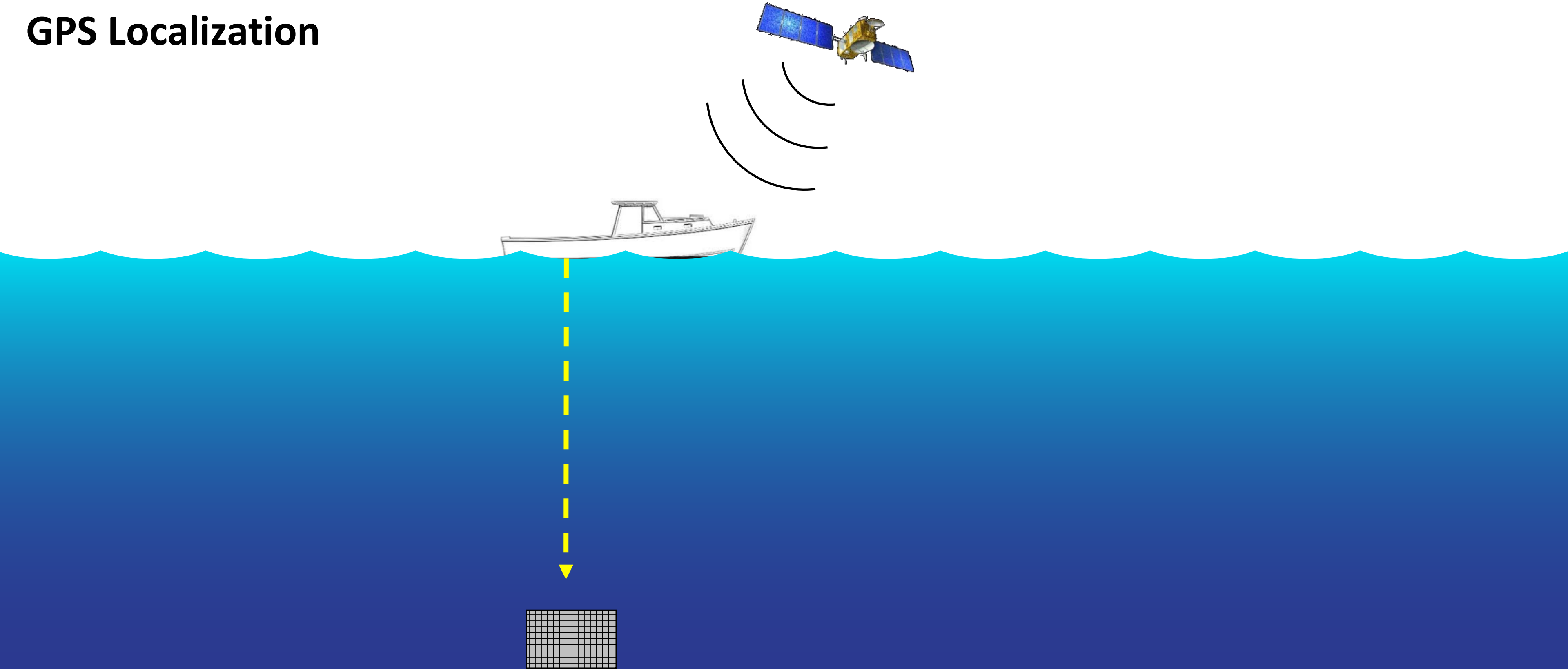
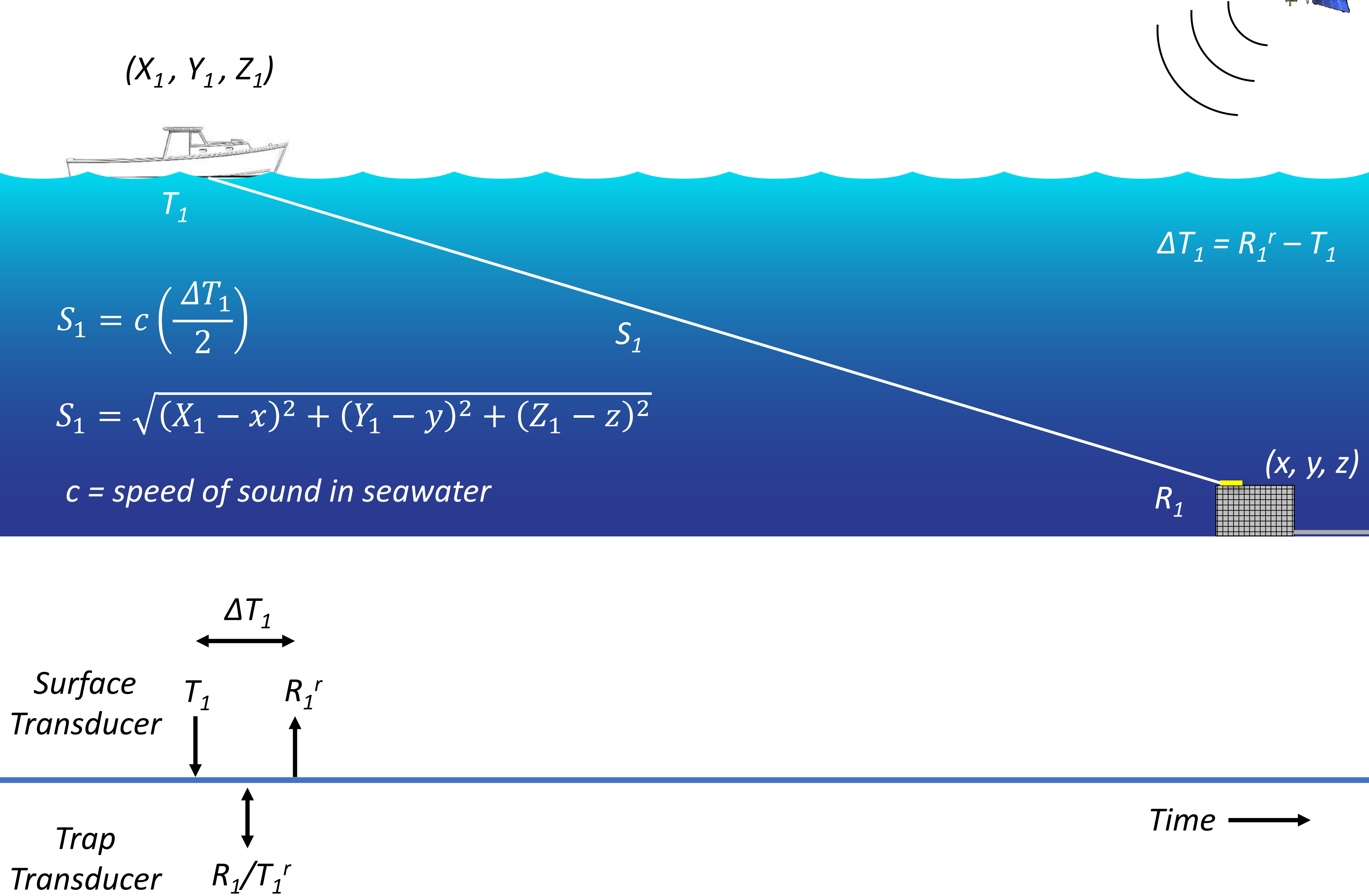
GPS Localization



Ranging Localization

Ranging Localization



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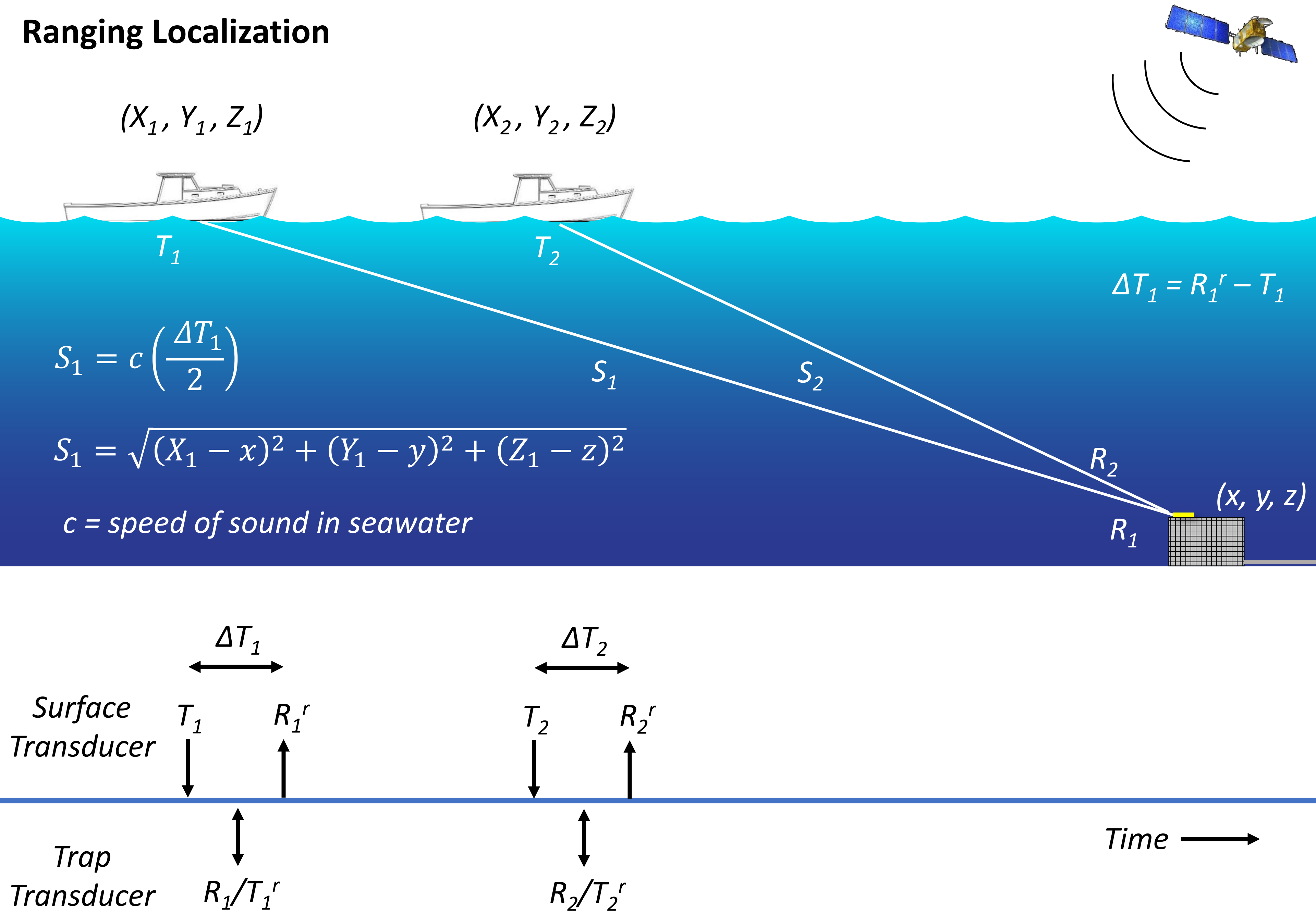
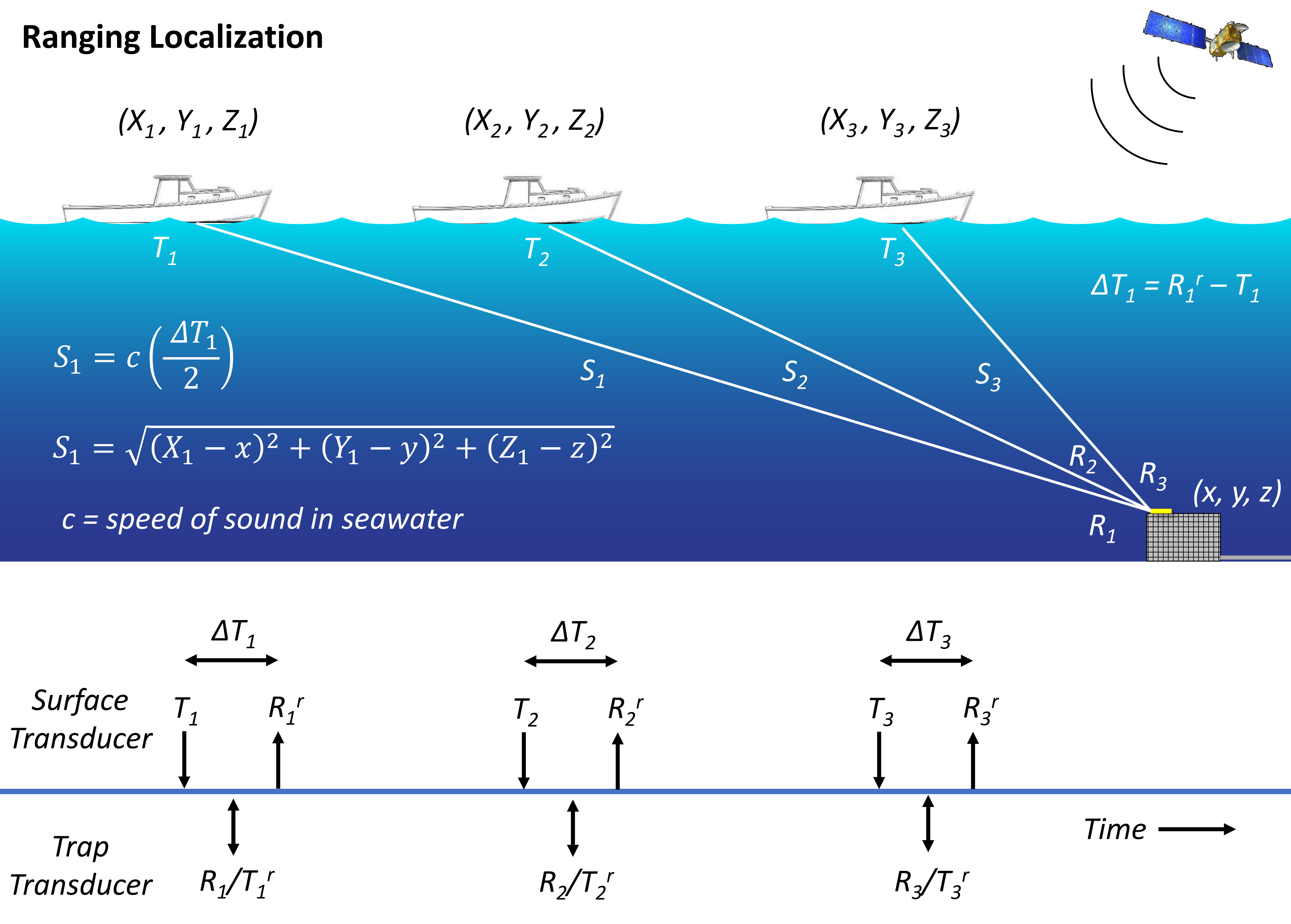
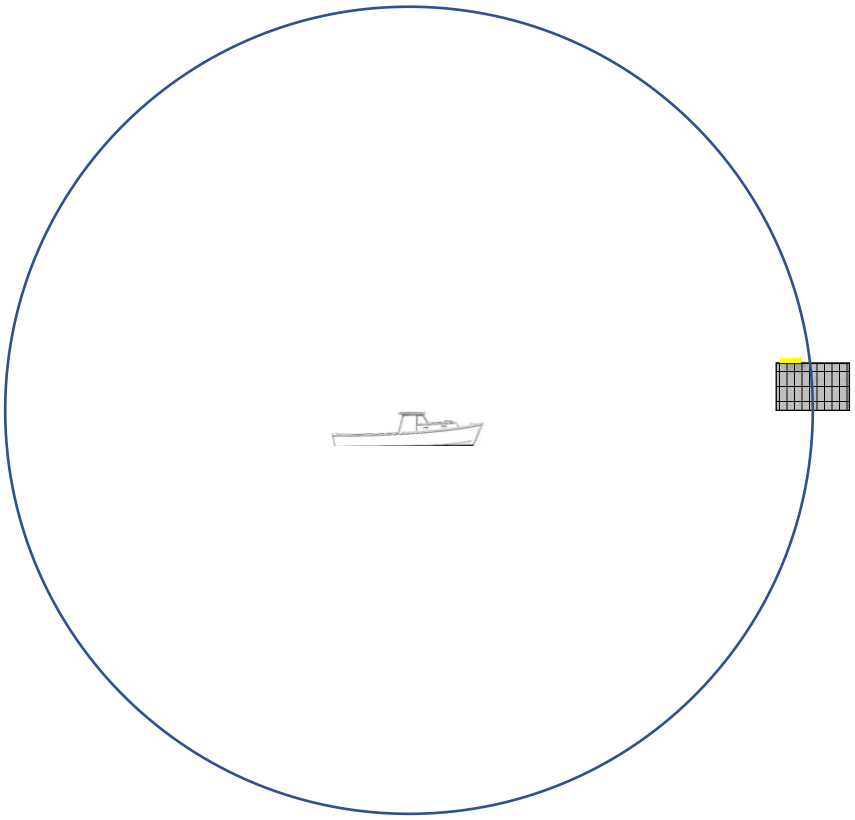


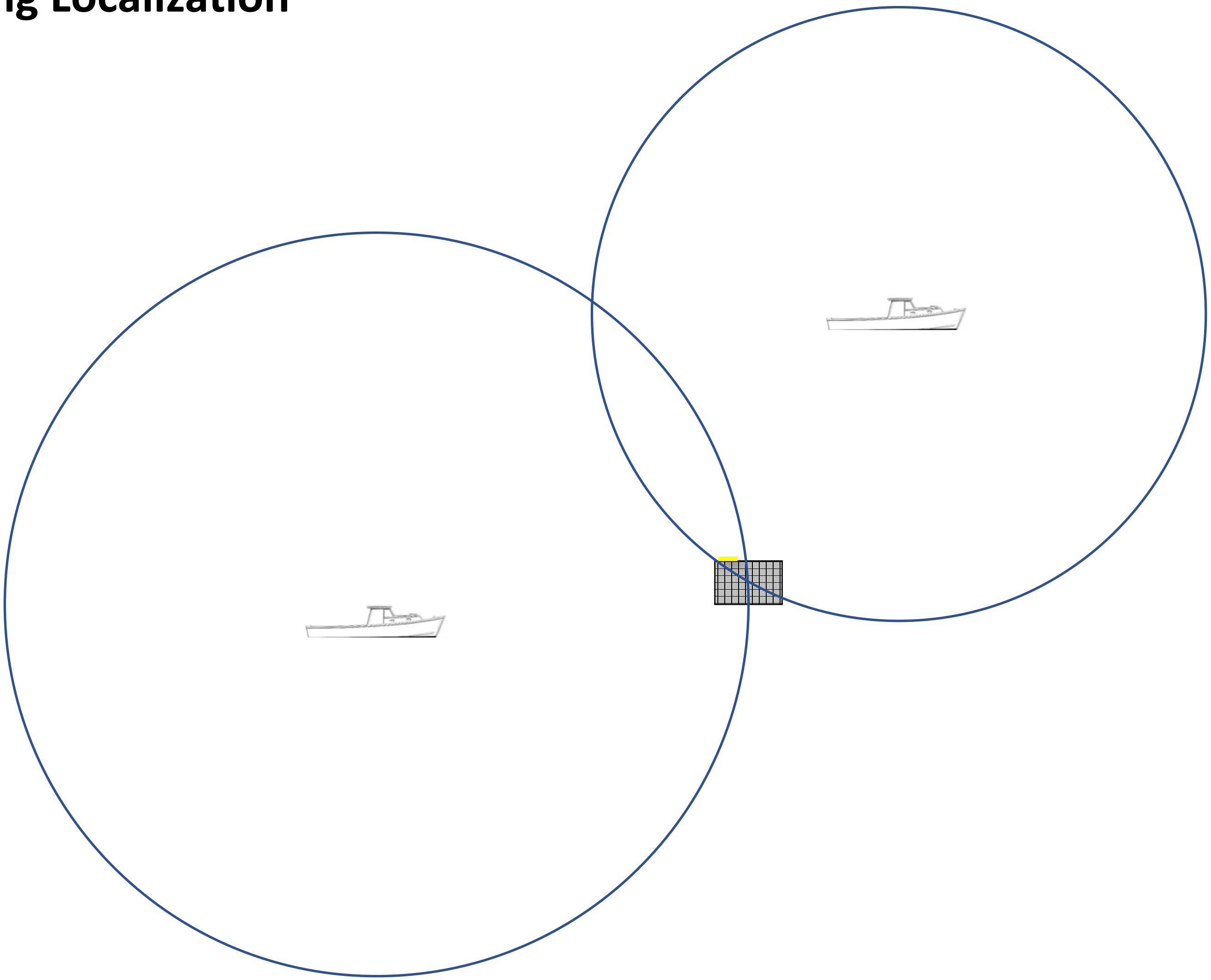

Ranging Localization
(X_1, Y_1, Z_1)
(X_2, Y_2, Z_2)
(X_3, Y_3, Z_3)
T_1
T_2
T_3
$\Delta T_1 = R_1^r - T_1$
$S_1 = c\left(\frac{\Delta T_1}{2}\right)$
S_1
S_2
S_3
$S_1 = \sqrt{(X_1 - x)^2 + (Y_1 - y)^2 + (Z_1 - z)^2}$
R_2
R_3
(x, y, z)
R_1
c = speed of sound in seawater
ΔT_1
ΔT_2
ΔT_3
Surface Transducer
T_1
R_1^r
T_2
R_2^r
T_3
R_3^r
Trap Transducer
R_1/T_1^r
R_2/T_2^r
R_3/T_3^r
Time

Ranging Localization

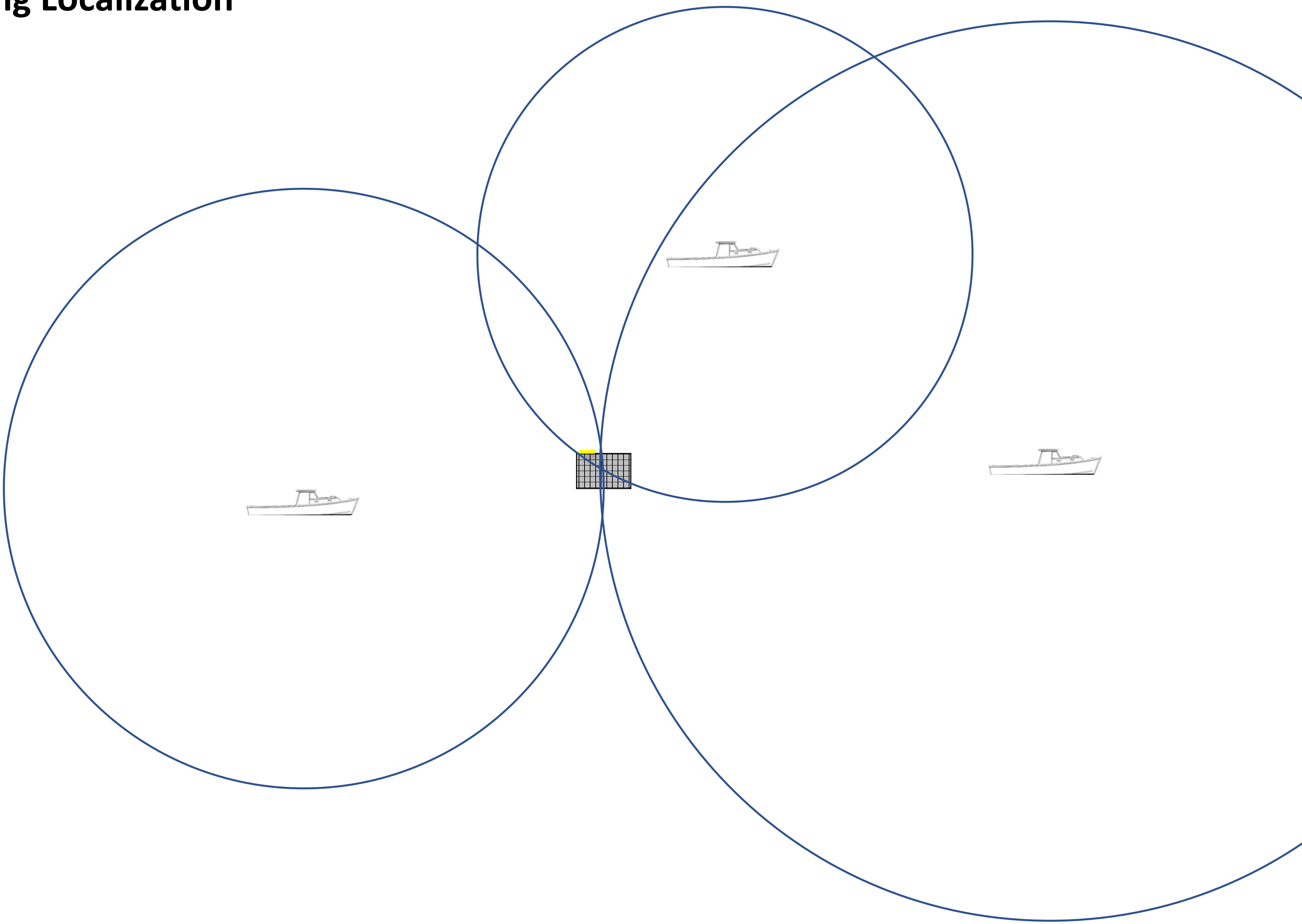
Ranging Localization



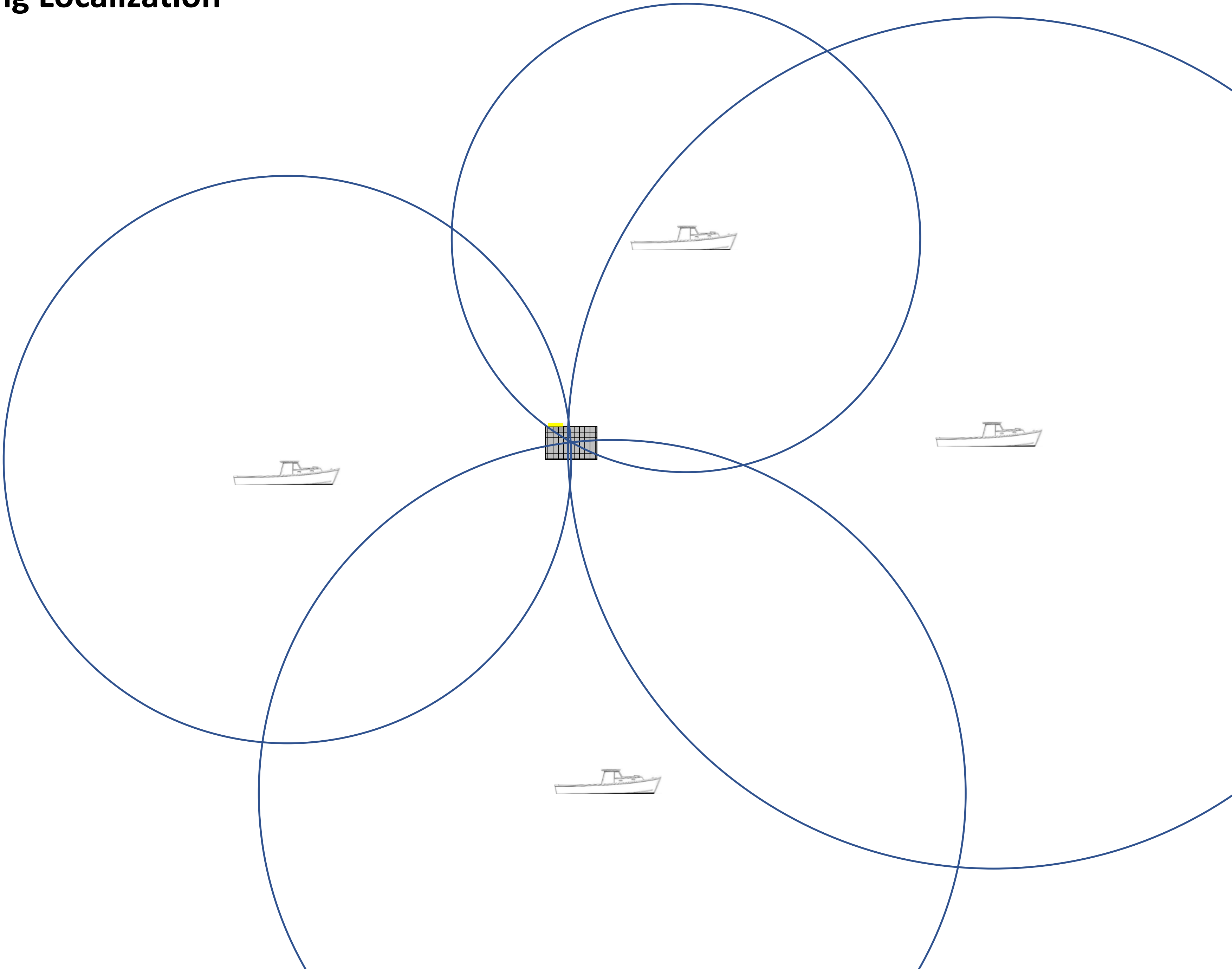
Ranging Localization



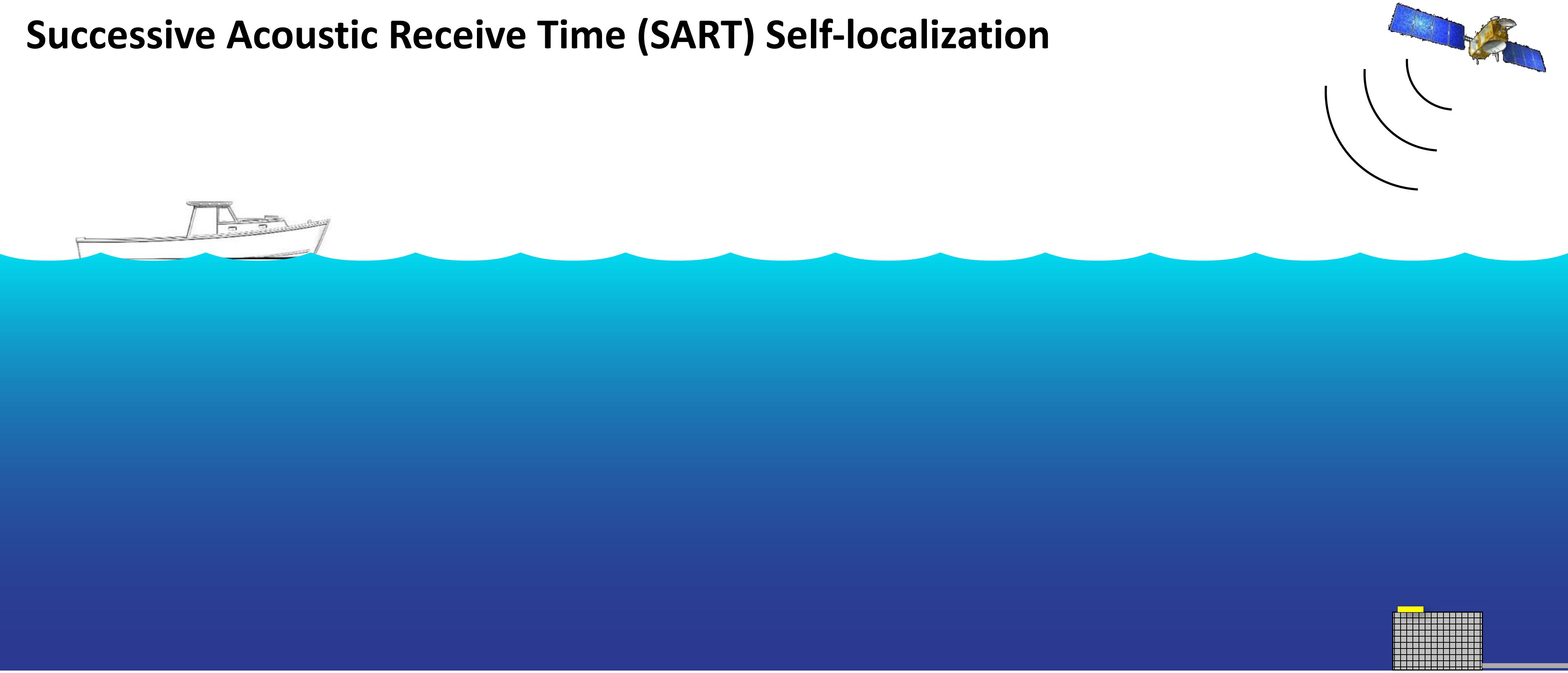
Ranging Localization



Ranging Localization



Successive Acoustic Receive Time (SART) Self-localization



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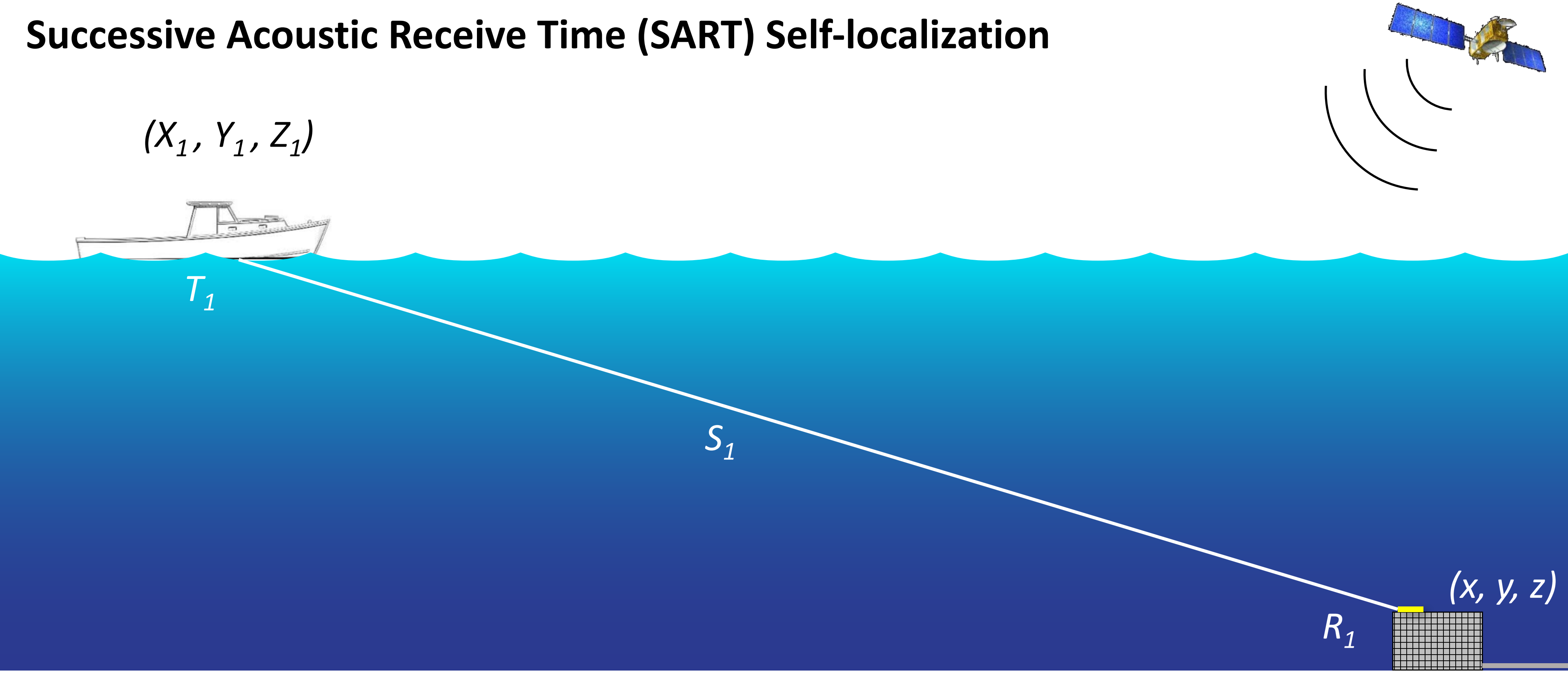

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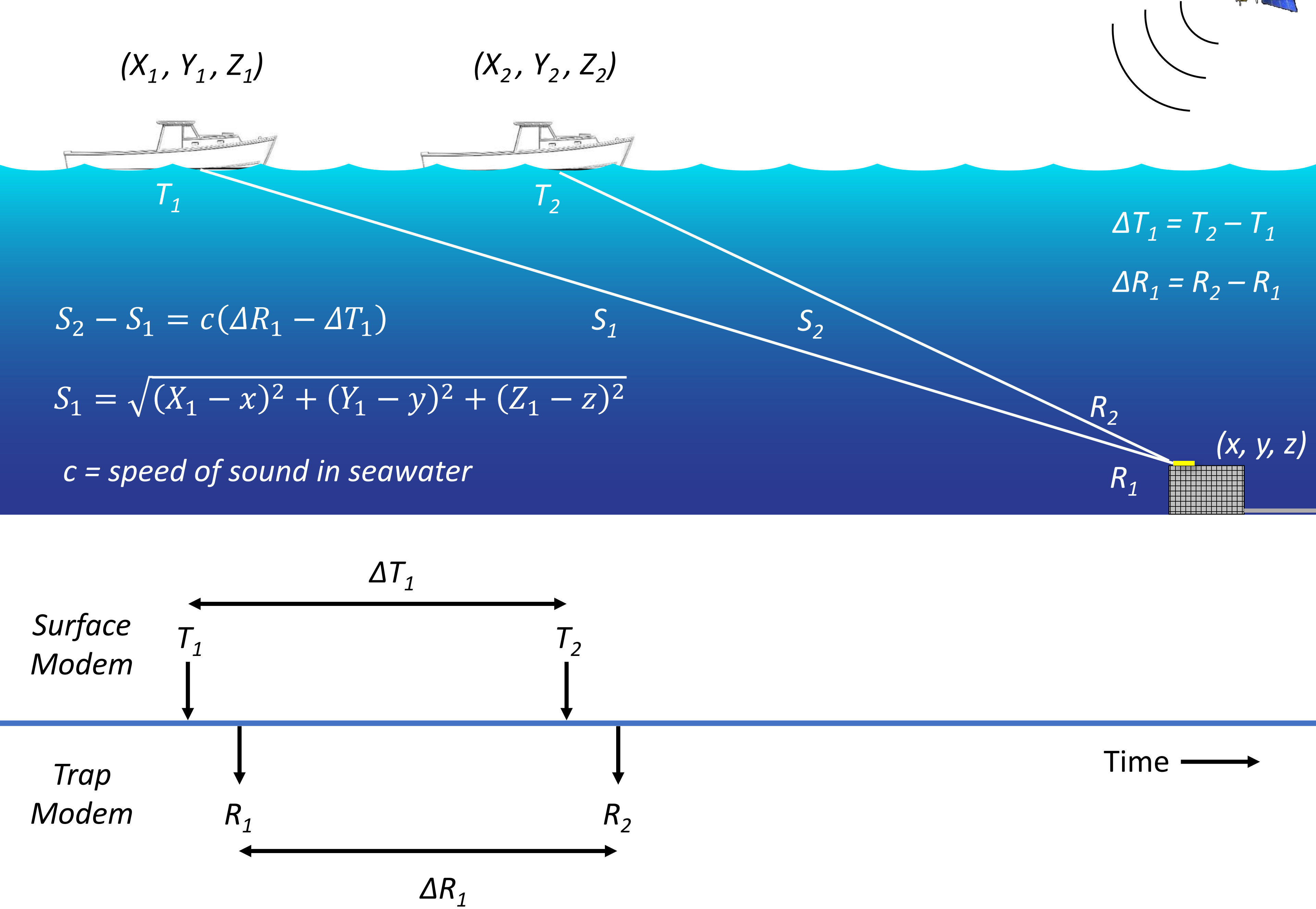

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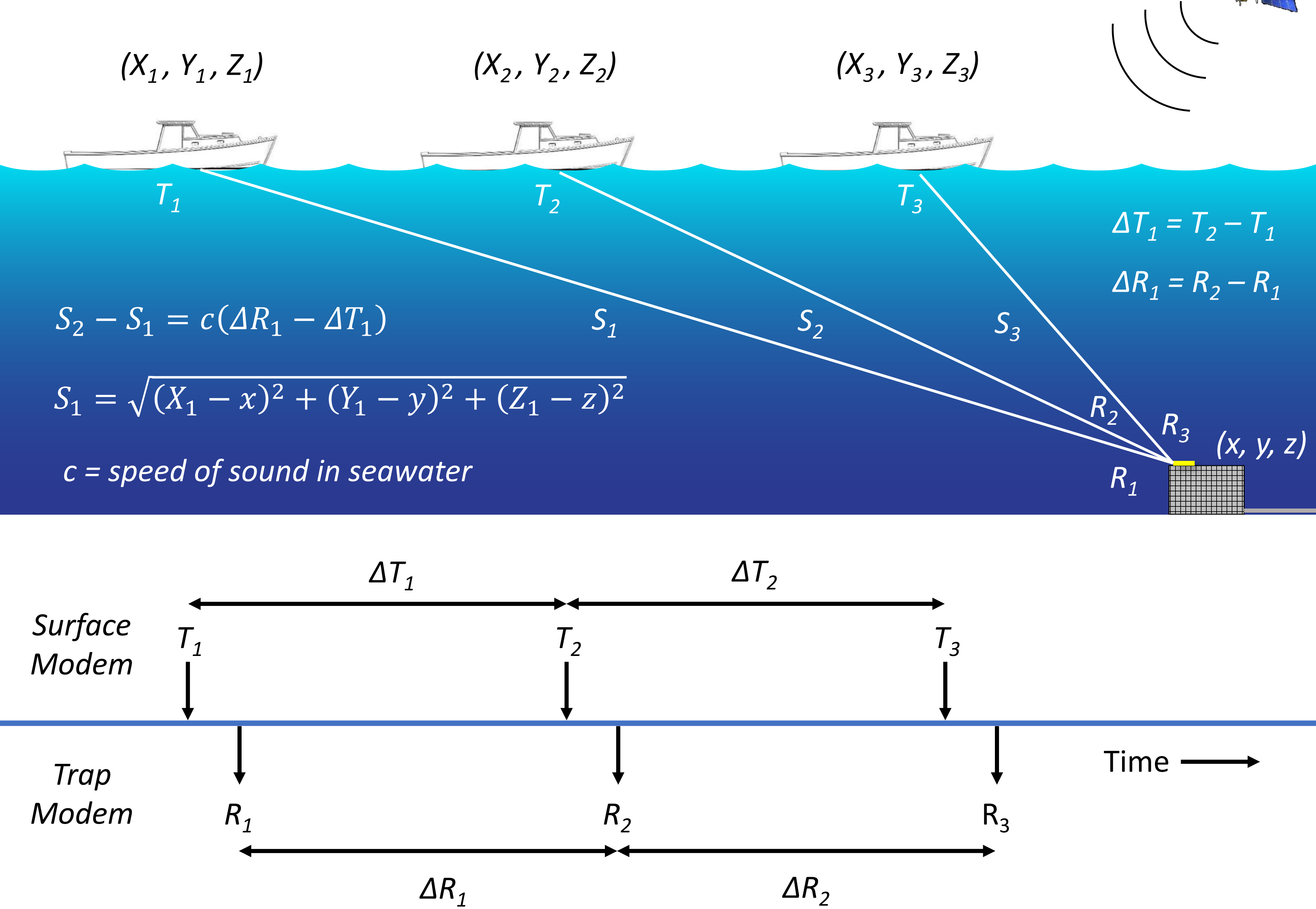

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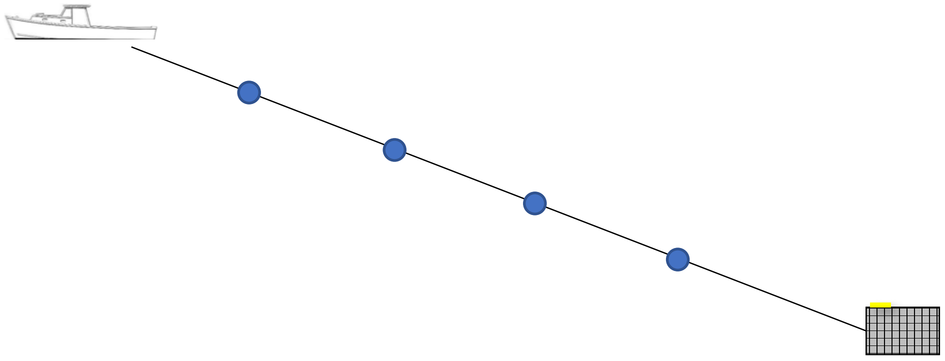

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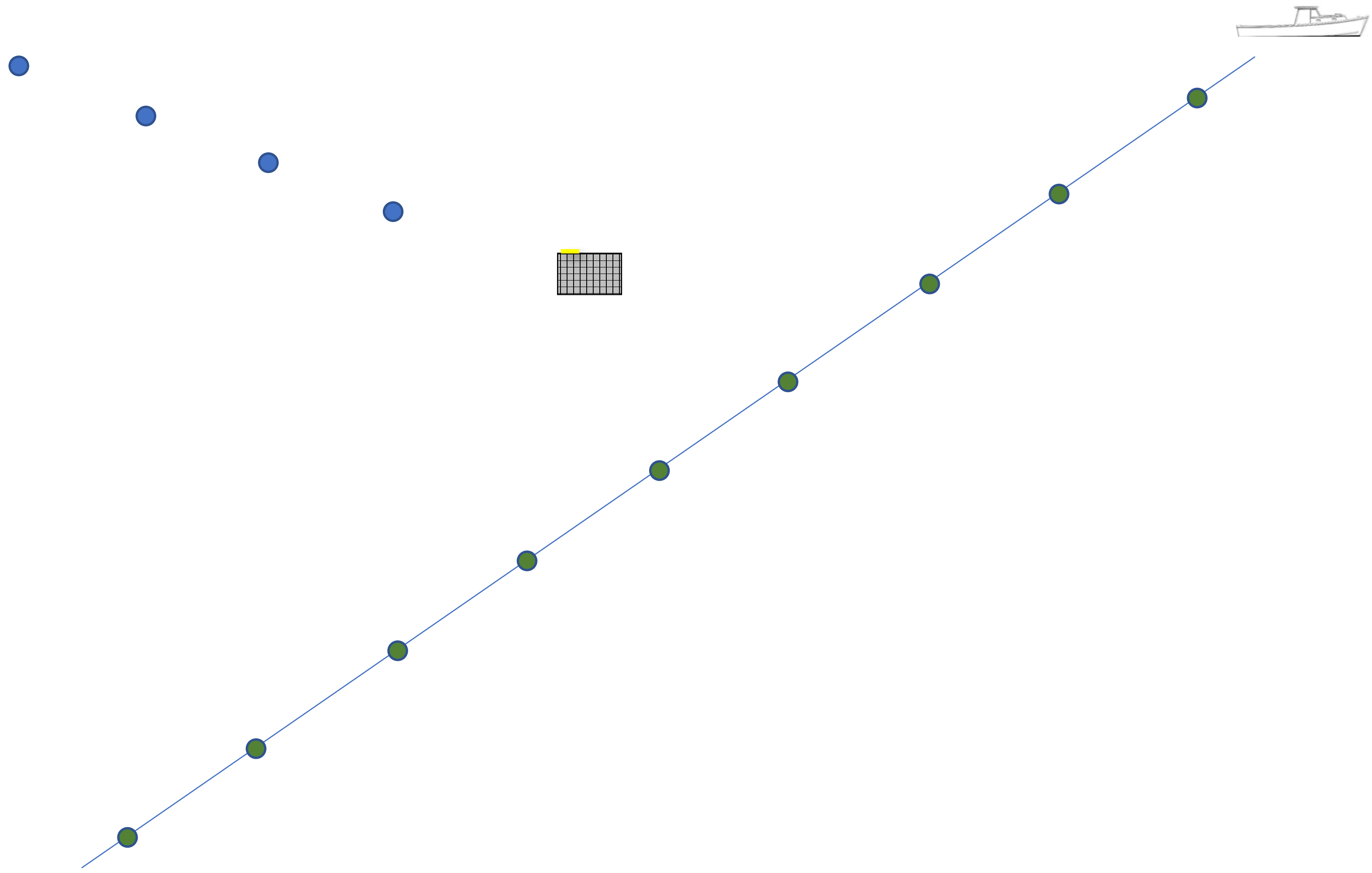

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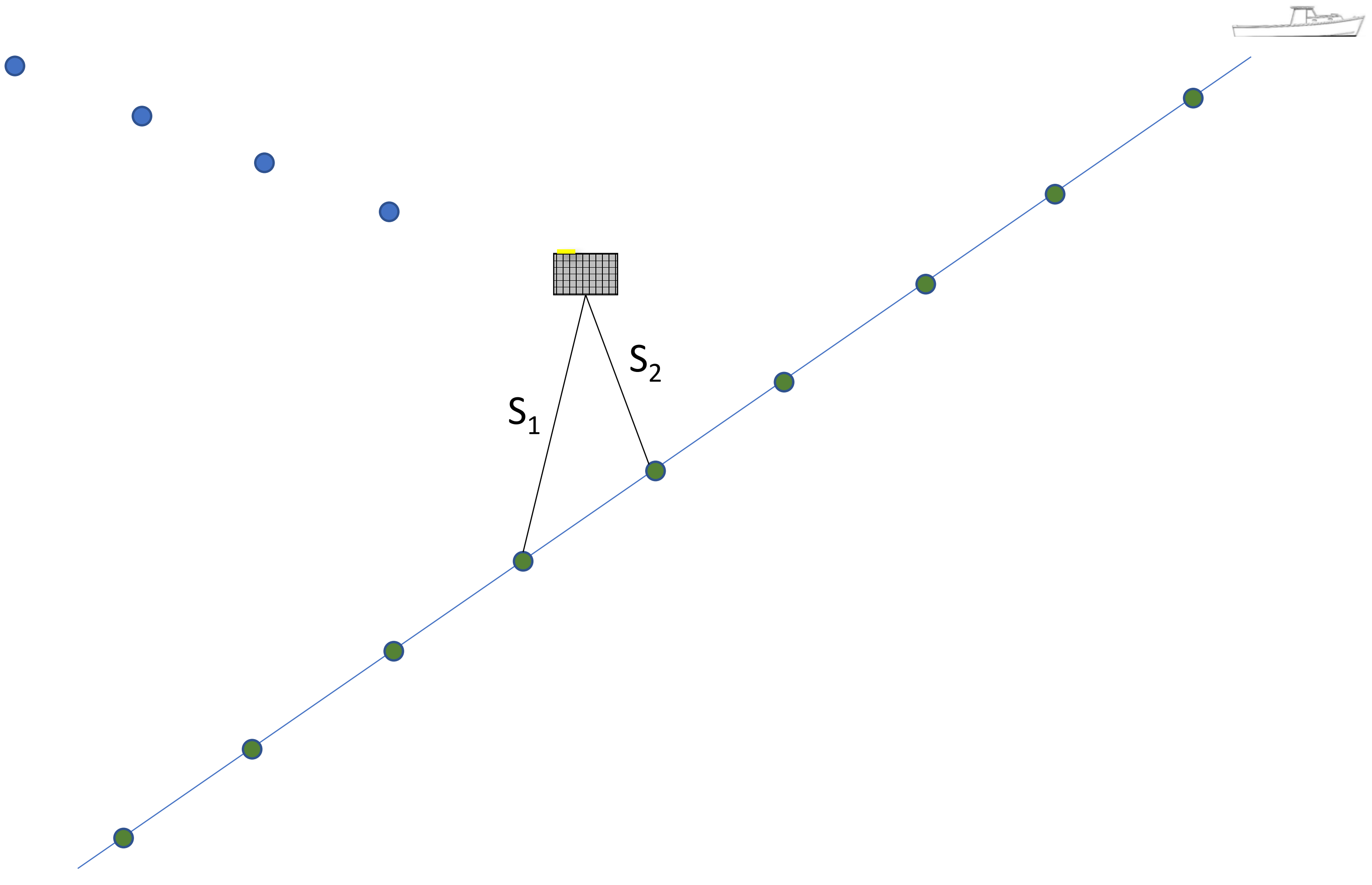
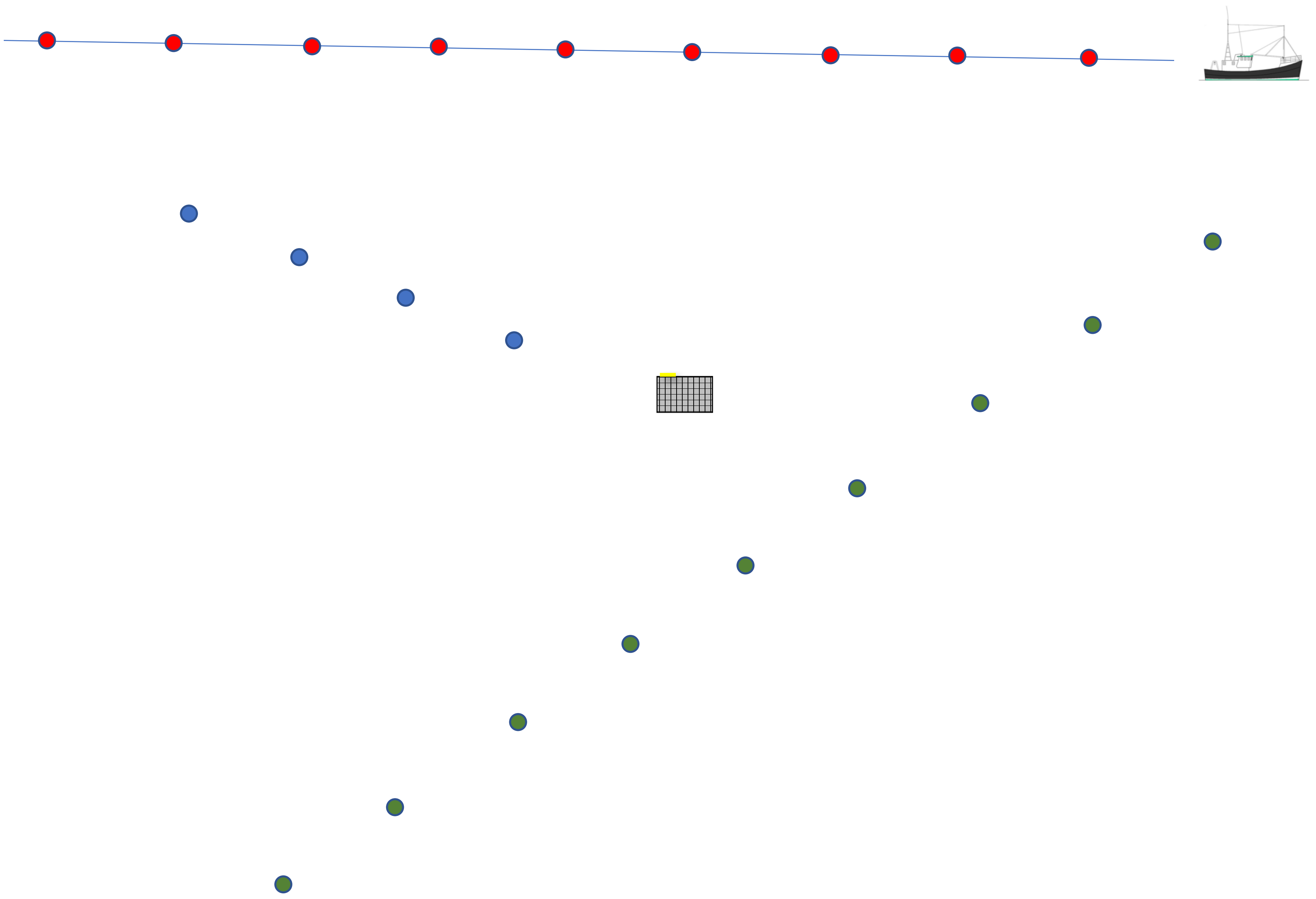


Successive Acoustic Receive Time (SART) Self-localization



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Borrowed some methods from:

IEEE Journal of Oceanic Engineering 33:146-157, 2008

Tracking Large Marine Predators in Three Dimensions: The Real-Time Acoustic Tracking System

Mark F. Baumgartner, Lee Freitag, *Member, IEEE*, Jim Partan, Keenan R. Ball, and Kenneth E. Prada

Work to date

Simulations

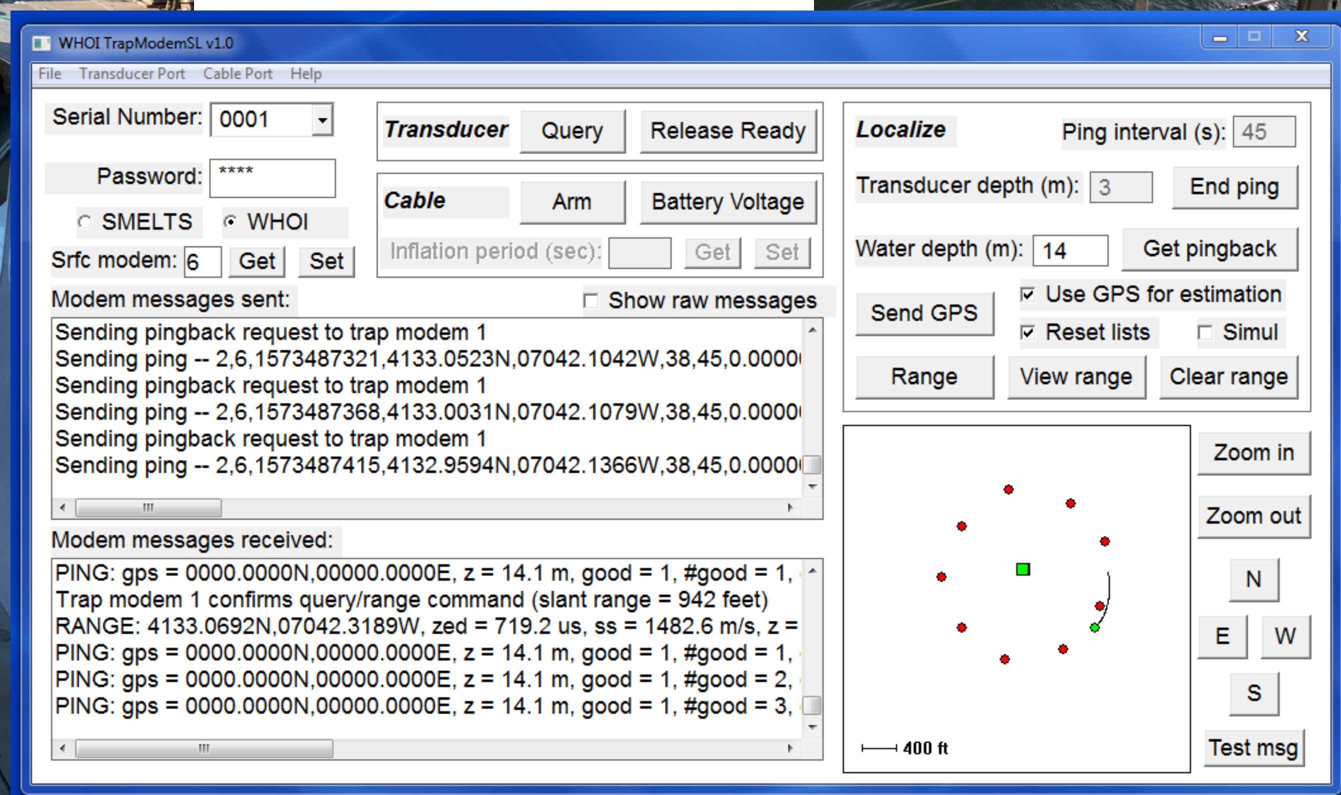
- Worked out the math
- Developed trial software in IDL programming environment
- Converted algorithm to C programming language
- Conducted many simulations to refine and test
- Ported C code to WHOI Micromodem
- Built PC app to control surface modem and display/map data
- Bench tested Micromodem with simulated data

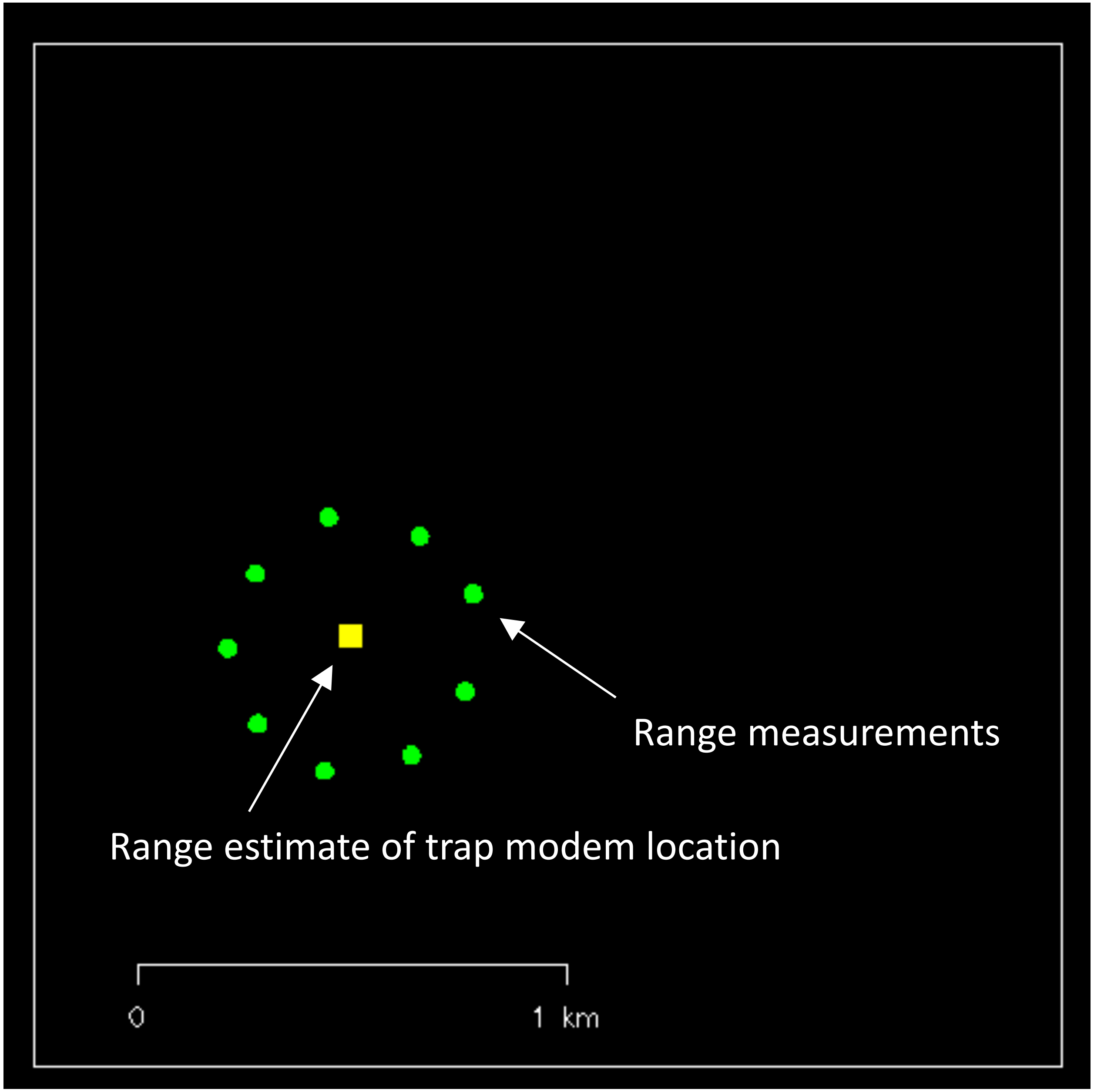
Field tests

- Moored trap modem in Buzzards Bay (14 m depth)
- Attached logging GPS to surface float
- Used ranging facility to estimate position of trap modem at sea floor
- Conducted ship transects away and past the trap modem to estimate position of trap modem at sea floor with SART

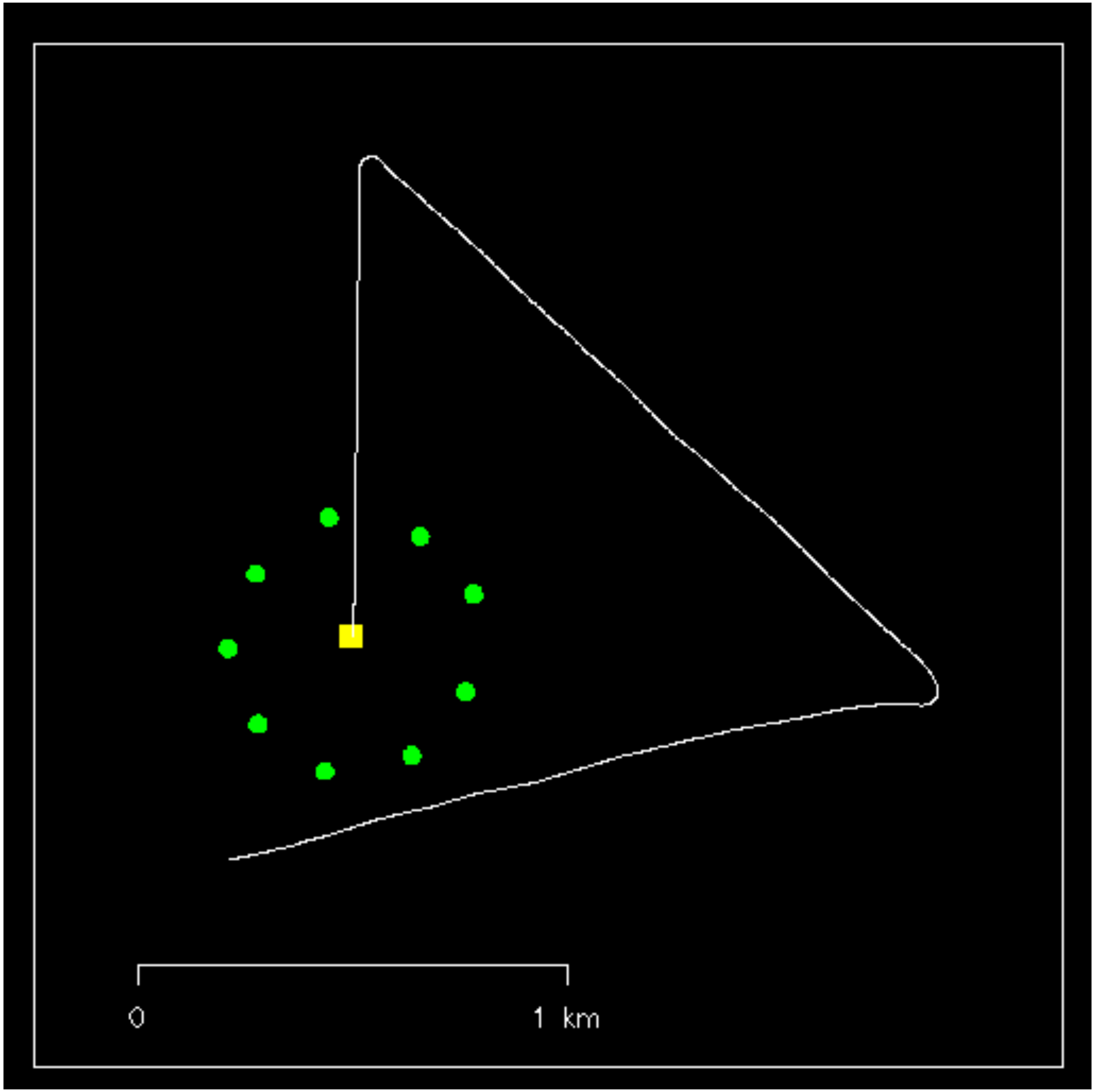

CAPACITY 4600 lbs



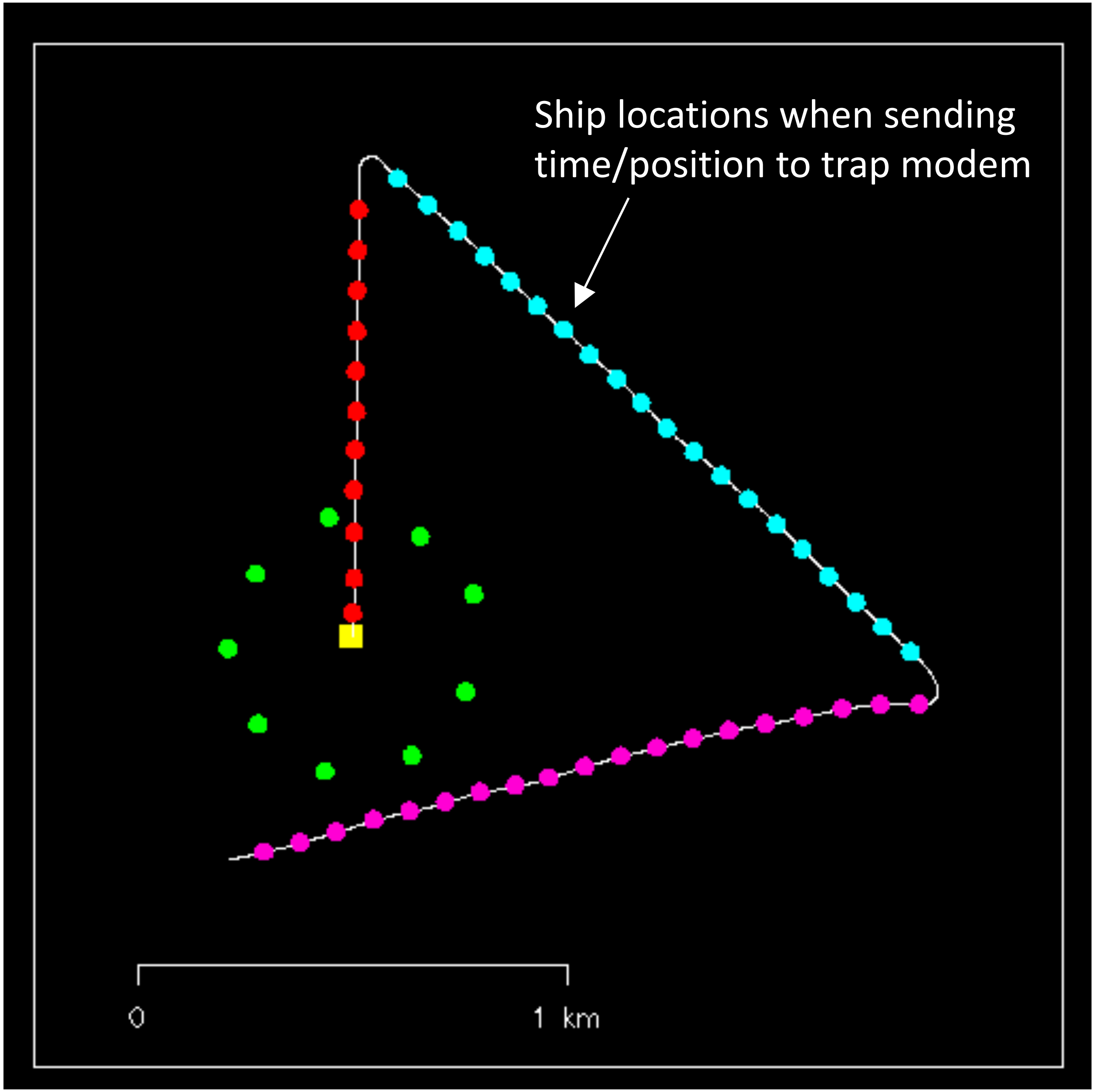

WHOI TrapModemSL v1.0
File
Transducer Port
Cable Port
Help
Serial Number: 0001
Password: ****
SMELTS
WHOI
Srfc modem: 6
Get
Set
Transducer
Query
Release Ready
Cable
Arm
Battery Voltage
Inflation period (sec):
Get
Set
Localize
Ping interval (s): 45
Transducer depth (m): 3
End ping
Water depth (m): 14
Get pingback
Send GPS
Use GPS for estimation
Reset lists
Simul
Range
View range
Clear range
Modem messages sent:
Show raw messages
Sending pingback request to trap modem 1
Sending ping -- 2,6,1573487321,4133.0523N,07042.1042W,38,45,0.0000
Sending pingback request to trap modem 1
Sending ping -- 2,6,1573487368,4133.0031N,07042.1079W,38,45,0.0000
Sending pingback request to trap modem 1
Sending ping -- 2,6,1573487415,4132.9594N,07042.1366W,38,45,0.0000
Modem messages received:
PING: gps = 0000.0000N,00000.0000E, z = 14.1 m, good = 1, #good = 1,
Trap modem 1 confirms query/range command (slant range = 942 feet)
RANGE: 4133.0692N,07042.3189W, zed = 719.2 us, ss = 1482.6 m/s, z =
PING: gps = 0000.0000N,00000.0000E, z = 14.1 m, good = 1, #good = 1,
PING: gps = 0000.0000N,00000.0000E, z = 14.1 m, good = 1, #good = 2,
PING: gps = 0000.0000N,00000.0000E, z = 14.1 m, good = 1, #good = 3,
400 ft
Zoom in
Zoom out
N
E
W
S
Test msg

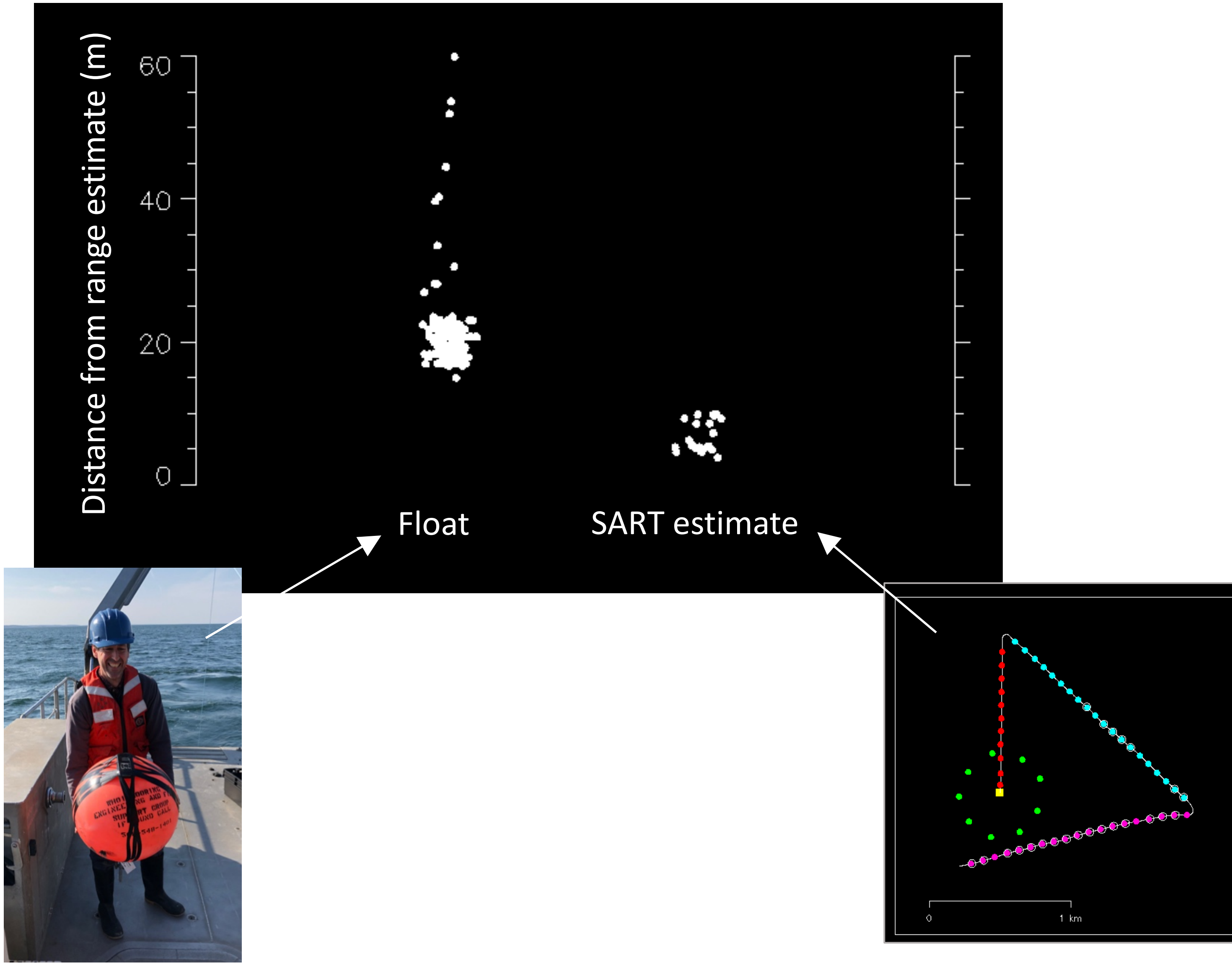


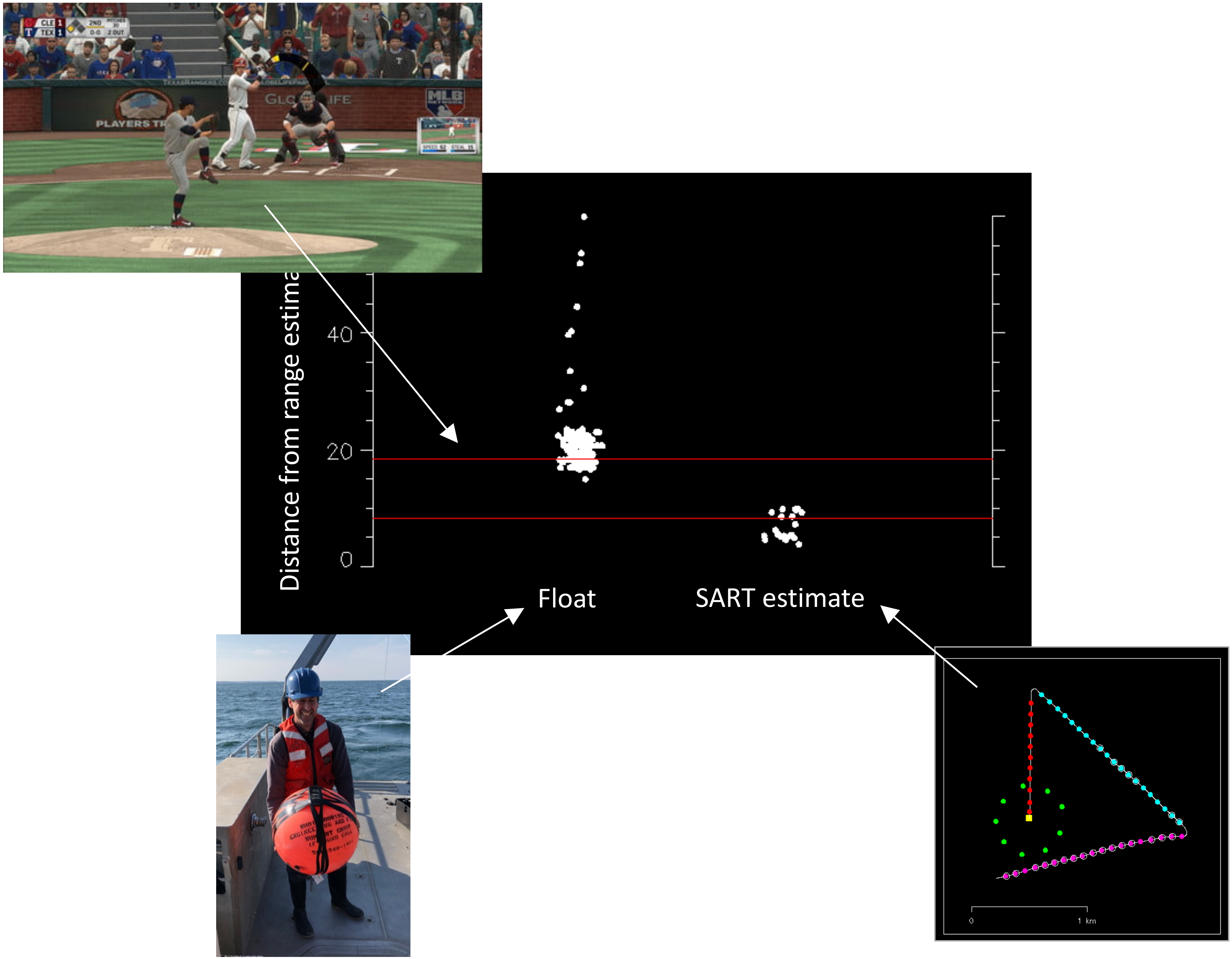
Range measurements
Range estimate of trap modem location
0
1 km

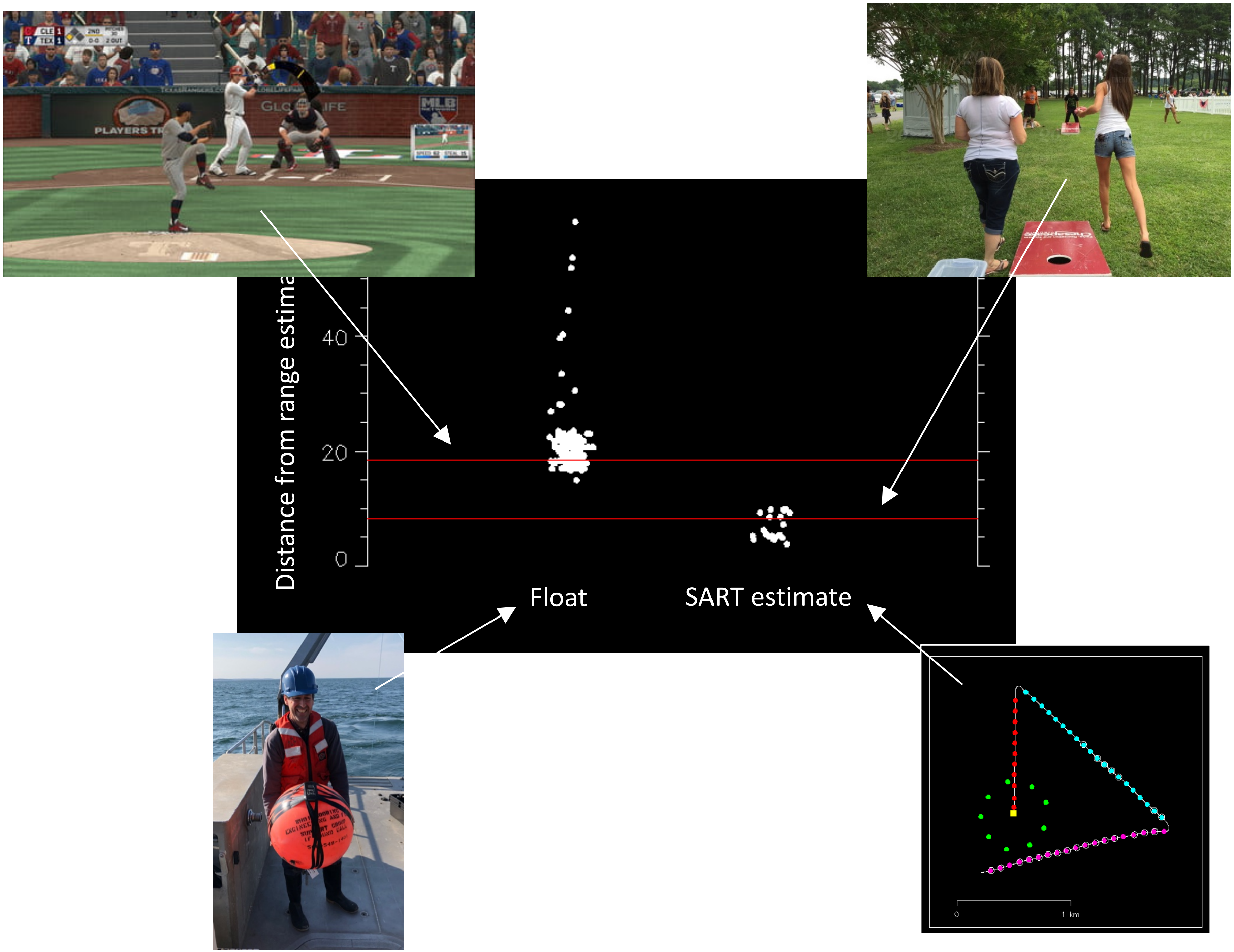


0
1 km


Ship locations when sending time/position to trap modem
0
1 km


Distance from range estimate (m)
60
40
20
0
Float
SART estimate
0
1 km


Distance from range estima
40
20
0
Float
SART estimate
0
1 km



Distance from range estima
40
20
0
Float
SART estimate
0
1 km

Next steps

Just completed first in-water tests in the past week

Using dock and at-sea results, refine algorithm

Test again at sea to verify functionality and evaluate accuracy

Publish methods in a peer-reviewed journal and make the code freely available

Work with interested acoustic modem manufacturers to implement SART localization

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Surface GPS

Pros
- Relatively easy to implement
- Does not require acoustic capability
- Relatively inexpensive

Cons
- Trap location accuracy can be low when deployed in currents
- Accuracy degrades significantly if trap moves
- Could significantly contribute to ghost gear, since gear that moves a substantial distance from the deployment site cannot be relocated

Ranging

Pros

- More accurate than surface GPS position alone
- Can account for traps that move from their surface deployment location

Cons

- Requires acoustic capability
- Requires trap be surveyed by each ship that wants to know its location
- Requires significant power, since trap modem is transmitting often
- Introduces sound in the water
- Information for localization resides on vessel, not on the trap modem
- Can be abused by a non-owner who constantly ranges to the same trap modem to intentionally run down that device's batteries

SART self-localization

Pros

- More accurate than surface GPS position alone
- Can account for traps that move from their surface deployment location
- Likely as accurate as ranging localization
- Significantly reduces need for trap modem to transmit, thereby reducing power consumption
- Trap location is estimated and stored by the trap modem
- Can’t be “abused” by non-owners; trap modem communicates typically only once with passing ships (twice if location certainty changes)

Cons

- Requires acoustic capability
- Requires at least two ship passages for position estimate
- Introduces sound in the water, but attempts to minimize this over ranging localization

Acknowledgements

Assistance:

- John Kemp and Meghan Donahue – WHOI Mooring and Engineering Group
- Pete Collins and Leah Saunders – R/V Tioga

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