Genesis of Loran Augmented Satellite Navigation

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Synergy as an Engineering Tool

- Definition-the action of two or more approaches to achieve an effect of which each is individually incapable, e.g. working together

- Examples:
  - MIT Instrumentation Laboratory (Now Draper Laboratory)
    - Kamikaze-USN Mk 14/15 gunsight-gyro/optical/radar range
    - Korea-A1-Gun-bomb-rocket sight-inertial/optical/radar range
    - Inertial guidance-startracker updating
    - SINS-3 voting and Transit updating for Polaris Submarines

    - USAF WS 117 Satellite Program Guidance and Control
      - Mini-SINS IMU for AGENA ascent to orbit
      - SAMOS/MIDAS Gravity Gradient Stabilization on orbit
    - Corona Active On-Orbit Stabilization IMU + Horizon Sensor

Factors Determining Product and Market

- Shell's Torrey Canyon Runs Aground on Scilly Island
  - Major Oil Spill on UK and French Shores

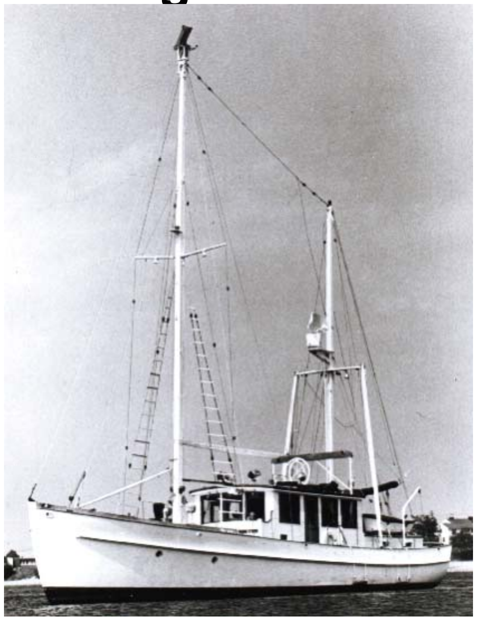
- Chevron Ships Collide Under Golden Gate
  - San Francisco Bay, worst place for major spill area

  - Integrated Display Needed to Prevent Both
    - Collisions and
    - Groundings
    - Easy to compare with ASPECT of other ships

  - Oil Companies are Targeted as Primary Customers
    - Super Tanker's dynamics-difficult to maneuver
    - Have Funds and High PR Motivation for Safety

Bridge Automation Equipment Functionality

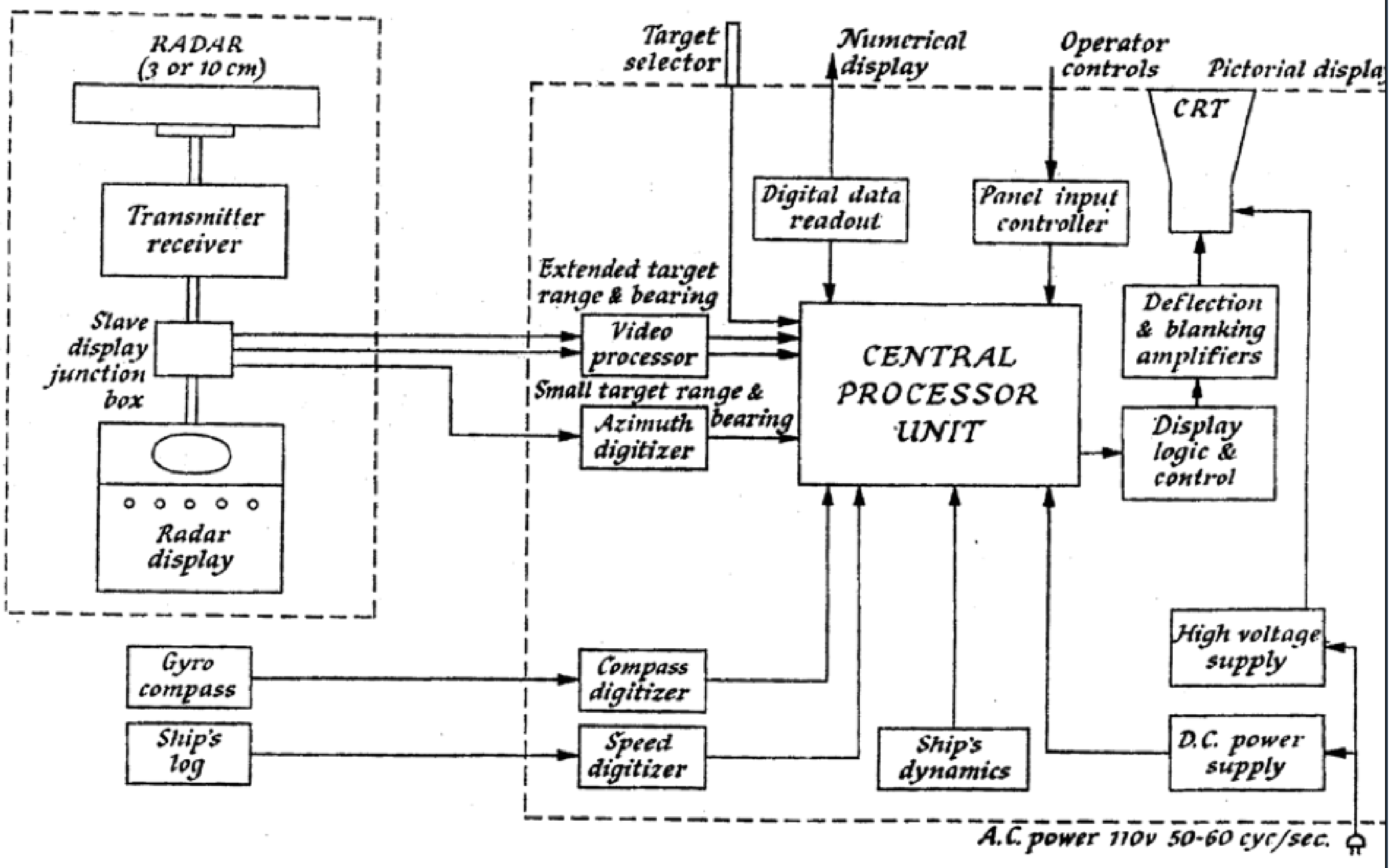
- Iotron AUTO-MATE- Collision Avoidance and Anti-Stranding Aids
  - "Self Plotting" Radar-later called IMO ARPA
  - Loran Augmented SatNav Navigation
  - Traffic Separation Charted Lanes on PPI
  - True Motion Trial Maneuver with Ship Dynamics
  - Situation Recorder



- Fuel Saving Adaptive Autopilot-Safety Cost Offset

- Future Bridge Automation-Low Cost for All Size Vessels
  - GNSS-eLoran Augmented Navigation
  - IMO ECDIS/ARPA-Single 3D Maneuvering Display
    - ARPA Superimposed on eCharts- for Depth Constraints
    - Correlated X and S Band Radar Integrity Improvement
    - Inner Harbor Ship Operation and Shore Surveillance

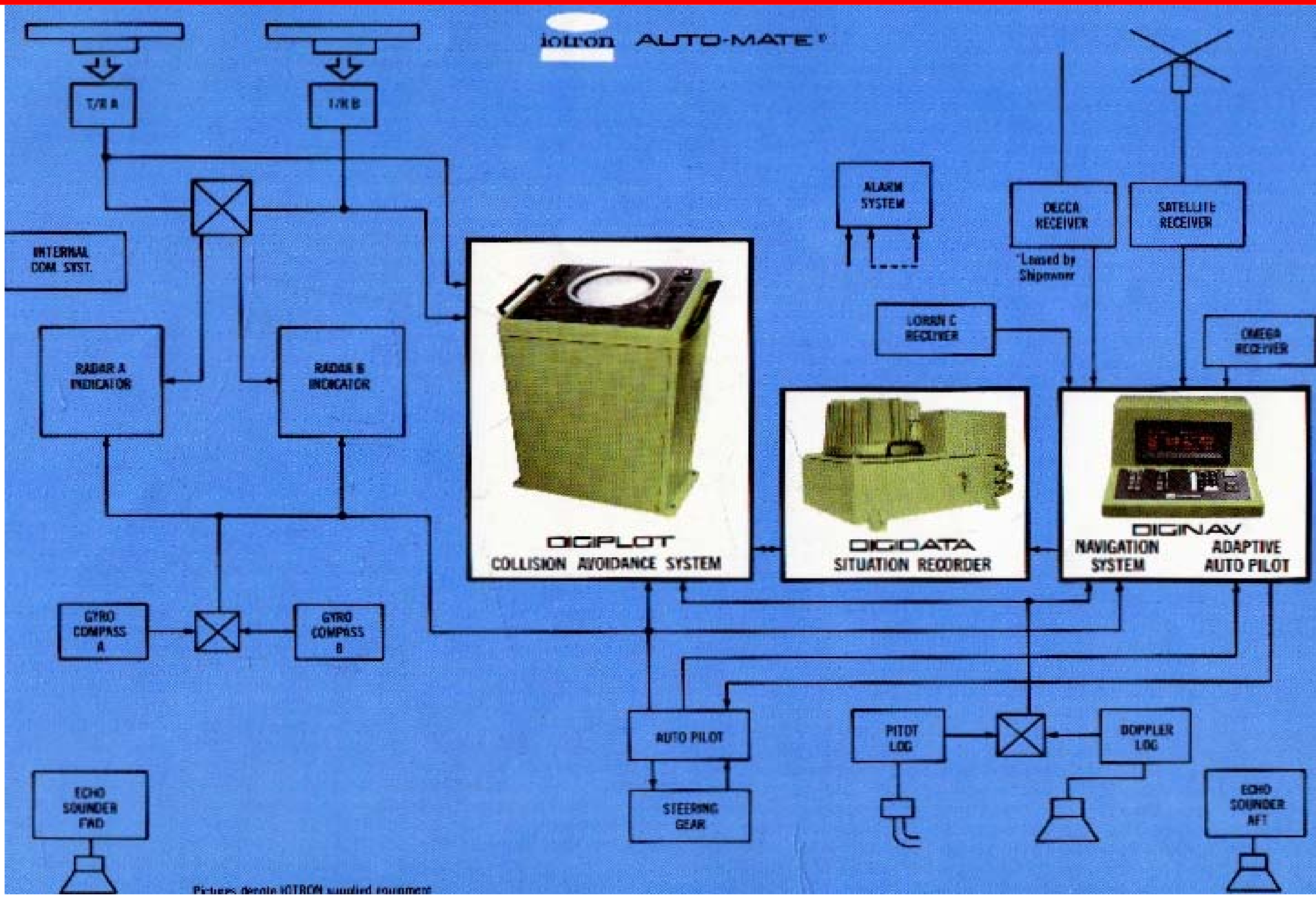
DIGIPLOT Original Design-1970



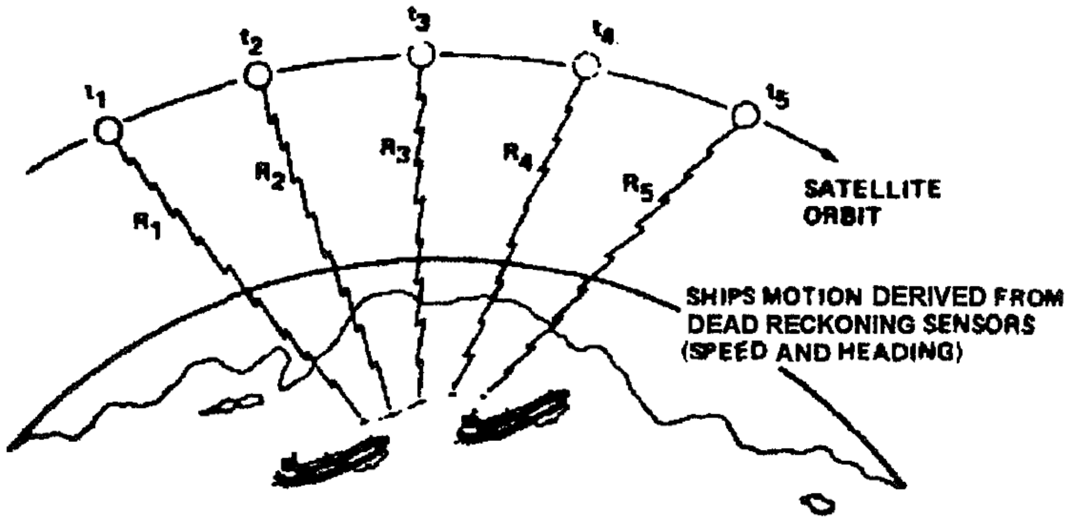
DIGIPLOT Showing Approach to NY Harbor

Figure shows a DIGIPLOT operatorÕs console showing a ÒHead UpÓ two-color radar PPI display on a 6 nm scale with 6-minute predicted future position vector lengths. Own ship is shown approaching New York harbor entrance with coastlines shown in green. Own shipÕs vector emanates from the PPI center with up to 40 other Òship-sized echoÓ moving vessel vectors and/or buoys shown as circles displayed in orange. True vectors show other vesselÕs present course with only a 15 second delay after a course change, thus providing other vesselÕs aspect which aids in following the rules-of-the-road in daylight maneuvering.

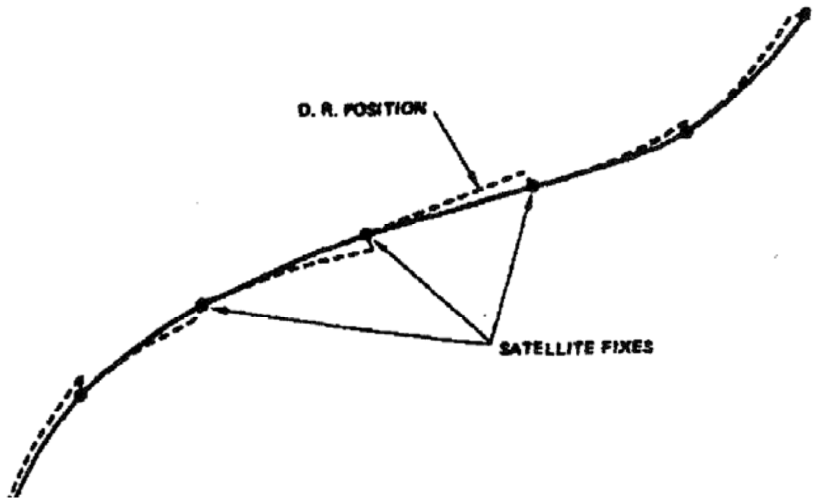
AUTO-MATE Equipment and Interconnections



Transit Satellite Orbital Path and Ship's Track

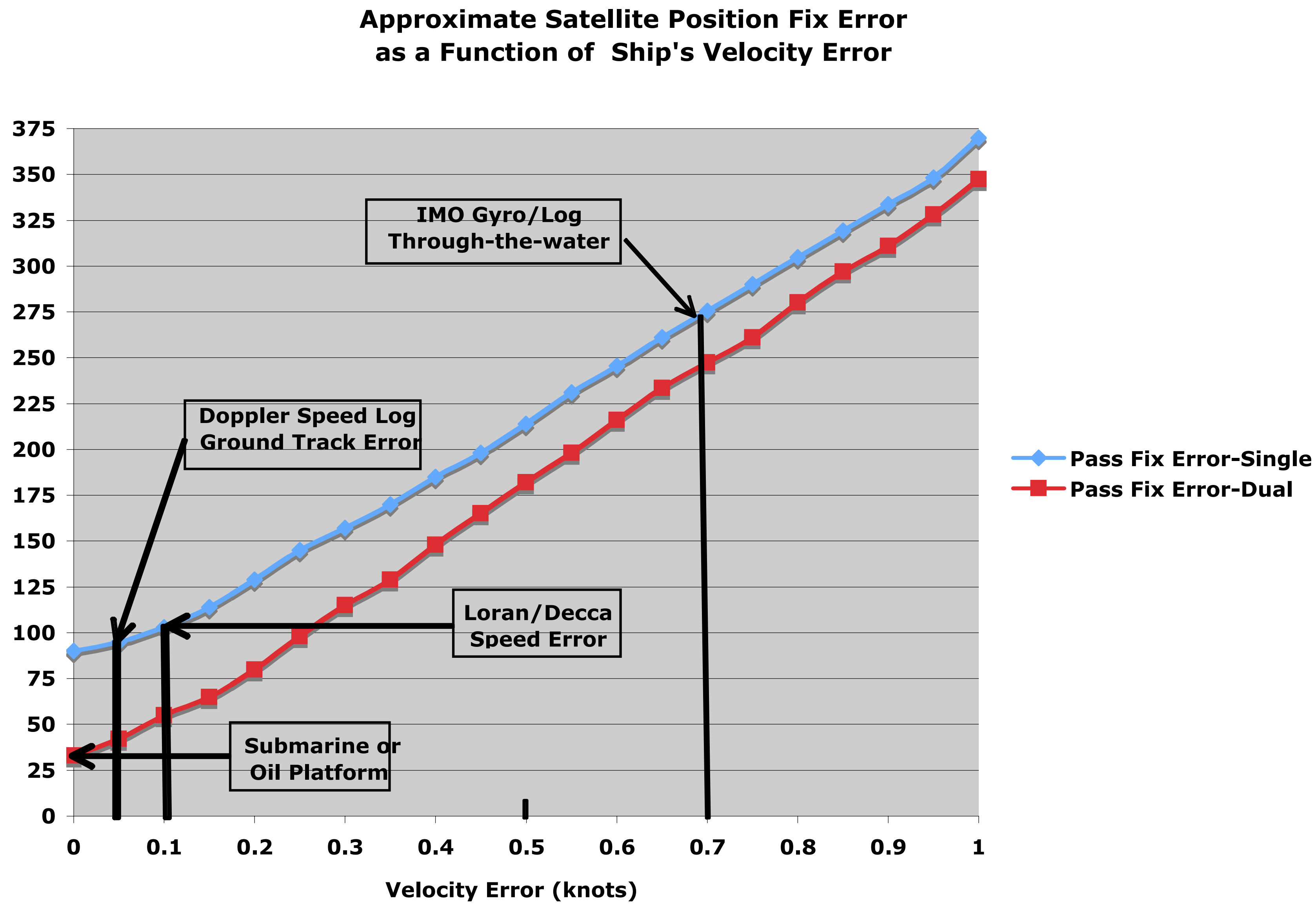


Transit and Ship Tracks During Intermittent Fixes



Dead Reckoned Path with Transit Updates

Position Fix Error vs. Unknown Velocity Error



Loran C Augmented SatNav Synergism

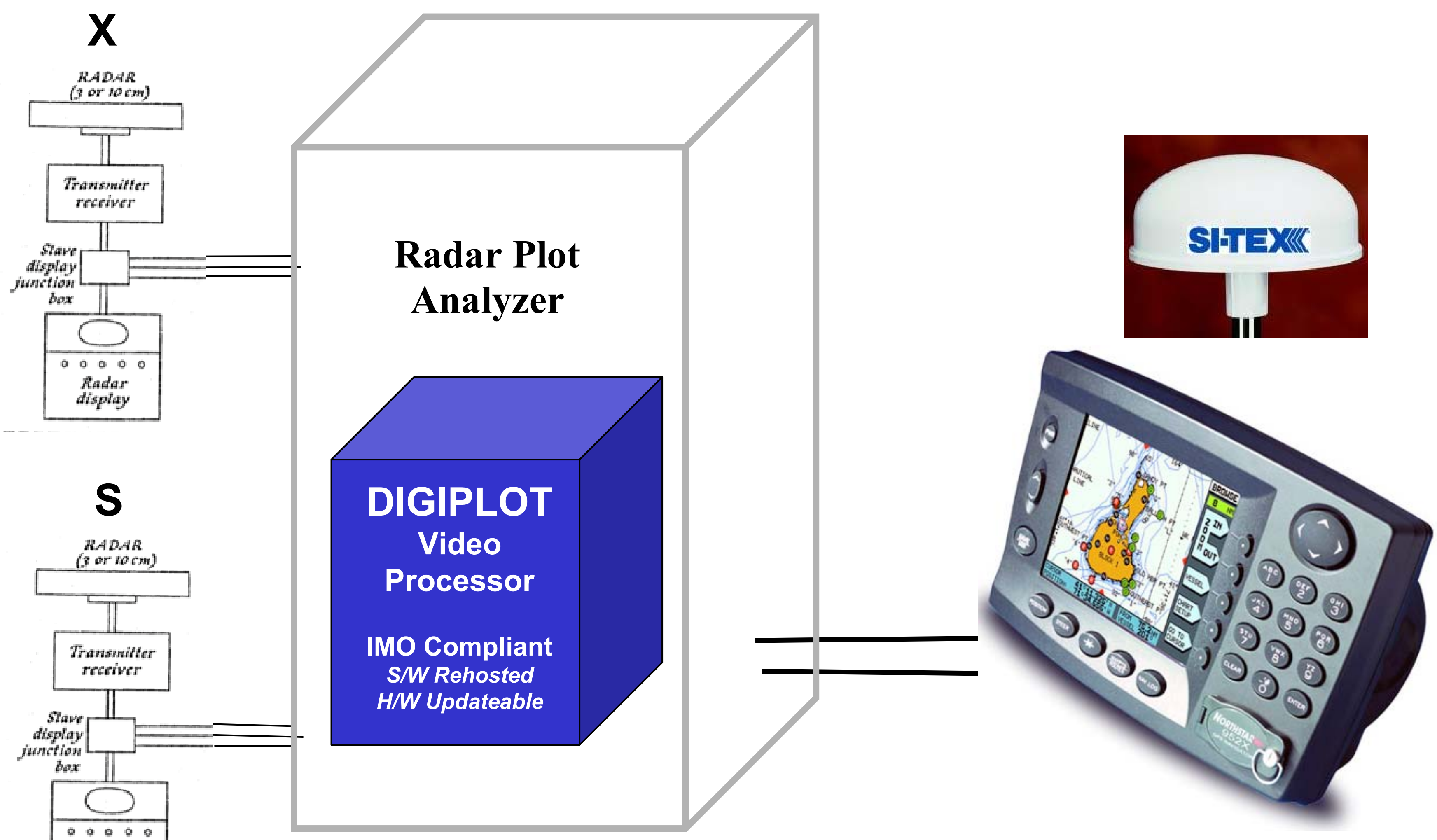
- Problem
  - Overcome Transit's intermittent, but accurate fixes to provide a continuous position source for displaying charted guide lines
  - Loran C accuracy alone < 460 m, not adequate
  - Transit Accuracy with IMO Standard gyro and through-the-water speed log accuracy approximately 500m in < 1.5 knot current
  - Near Shore, where charts needed, currents of 4 to 5 knots exist!

- Solution
  - Used the < 100 m Transit fixes to periodically update Loran C's 18 to 90 m repeatability accuracy for 34 Supertankers in 1980
  - This combination achieved PPI chart line accuracy of nearly 100-meters, that equaled GPS accuracy for 20 years until Selective Availability (SA) was removed in 2000

IMO Mandated Traffic Lanes in English Channel

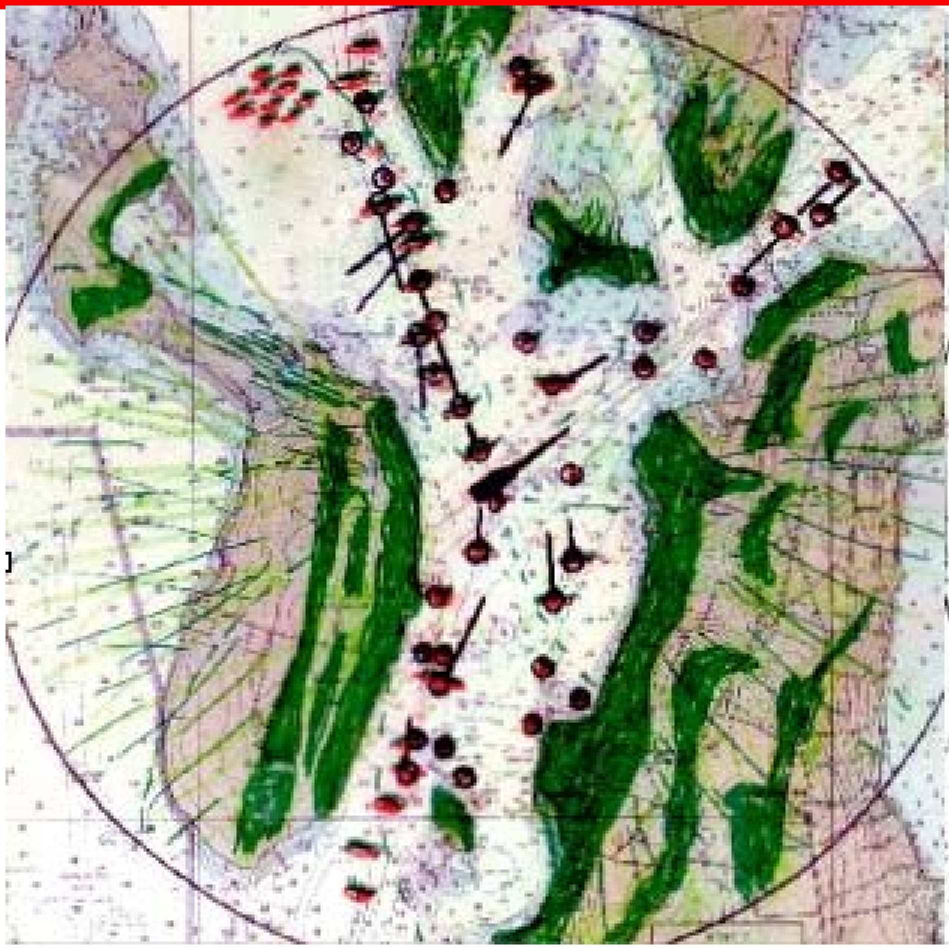
On the PPI Chart Line Positioning Accuracy Achieved:
1975 Single point Loran C Calibration < 0.1 nm-River Approach
1980 Transit updated Loran C ~100 m accuracy in currents

Chart plotter - X & S Band Radar ARPA/ECDIS



~8 X 8 x 30” 80’s technology

ARPA& Radar Superimposed on ECDIS Chart



Raw Radar and ARPA data on eChart

DIGIPLOT Echo-sketched
Radar and ARPA data on eChart

Future Marine Navigation Synergistic Vision

*ARPA for "Hands Off" self plotting radar technology is sea proven

- Can be repackaged and rehosted to plot and superimpose "see through radar" and ARPA data on charts rather than on the PPI
- X and S band radar can be simultaneously processed and synergistically combined for a significant integrity improvement
- Modern signal processing and availability of low cost digital processors and memory, permits modifications for a fully compliant ARPA to operate unattended inside harbors & rivers

*On vessels with any manufacturer's radars already installed

- Retrofit an auxiliary fully compliant ARPA Radar Plot Analyzer
- Combine a synergistically GNSS augmented eLoran receiver
- Add any manufacturer's ECDIS chart display
- This combination could result in the "long awaited AUTO-MATE type" integrated maneuvering aid for the prevention of collisions and groundings for 1/10th the 1980's cost!