Road to a Stronger Business Case for eLoran

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eLoran's Business Case ?

- We see more GPS than Loran receivers, Why??
- GPS does what users want it to do
  - Nearly always and nearly everywhere
  - At prices of about one refill of my car's fuel tank
    - True in Europe now; soon in the US as well ☺
- Loran is not available
  - US: not true, Europe: increasingly true, Asia: partly true, Worldwide: partly true

eLoran's Business Case - 2

- Loran receivers do meet accuracy and integrity requirements but…
- Loran receivers are too expensive
- Loran lacks appeal
- Loran is not mandatory in applications such as GPS will be in 911/112 cell phones
- Can we change that?

Receiver Development Process

- In the pre-GPS era, all merchant ships over 1600 gross tons in CONUS were required to carry a second navigation system which in practice was Loran-C
  - Is that still the case?
- This demand stimulated designing Loran receivers, especially in the United States
- Governmental hesitation in US and Europe on the future of Loran has paralyzing effect on receiver development investments

Chicken and Egg Situation

- There must be Loran signals to get users, but .....
- Absence of users may lead to dismantling the Loran infrastructure (European situation)
- US invested large amounts of capital (> 140 M$) in **research** and **upgrading** of Loran provider infrastructure
- US and Europe hardly invested in **receiver** research/development (Σ < 4 M$??) making it the weakest part of the eLoran navigation chain

The RDT&E eLoran Chain

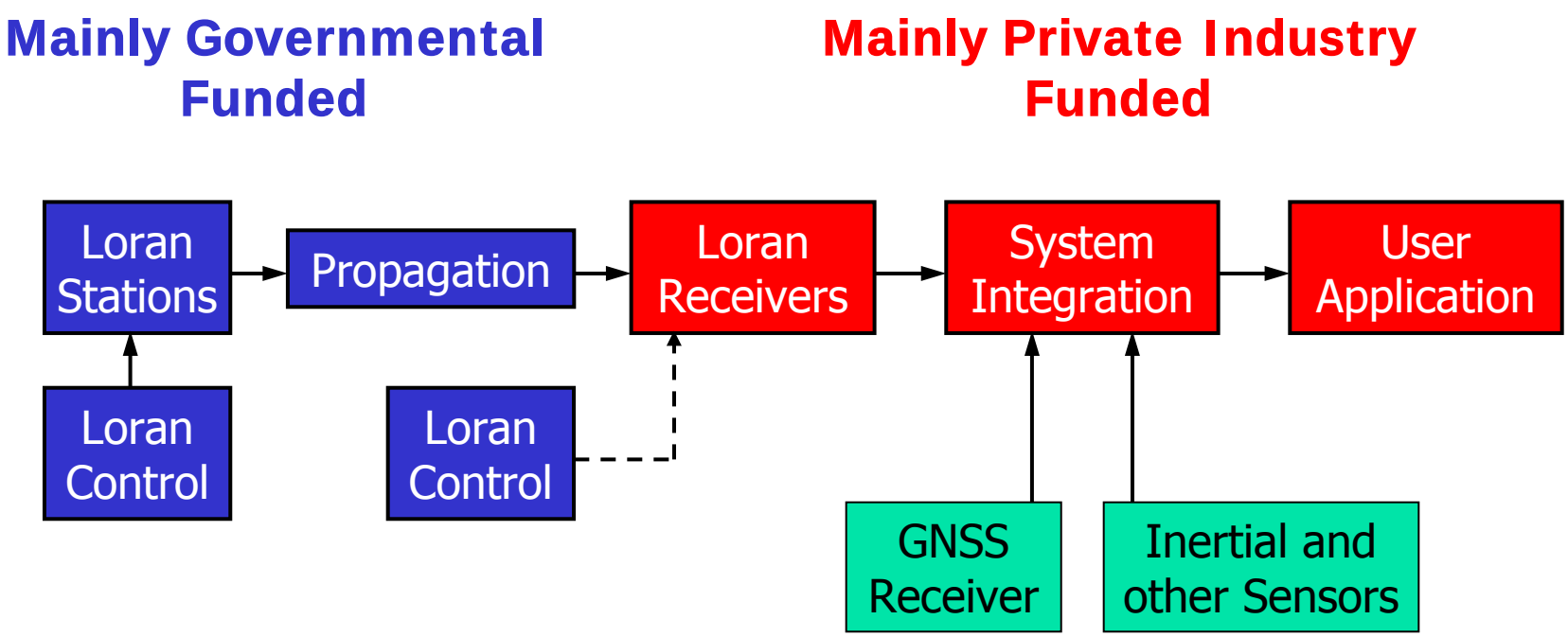

Table B.1

Basic GPS System Costs (1974–2016) (constant 1995 dollars in millions[a])

Cost Category	FY74–95	FY96[b]	FY97[b]	Balance to Complete	Total
Satellite	$3,897	$179	$225	$4,264	$8,565[c]
User Equipment	$3,277	$315	$378	$1,554	$5,524[d]
Total	$7,714	$494	$603	$5,818	$14,089

SOURCE: December 1994 *Selected Acquisition Report* (SAR).

[a]The SAR reports these figures in then-year dollars. They are adjusted to 1995 dollars here using DoD deflators.

[b]Estimated.

[c]For 118 satellites.

[d]For 161,298 user equipment sets.

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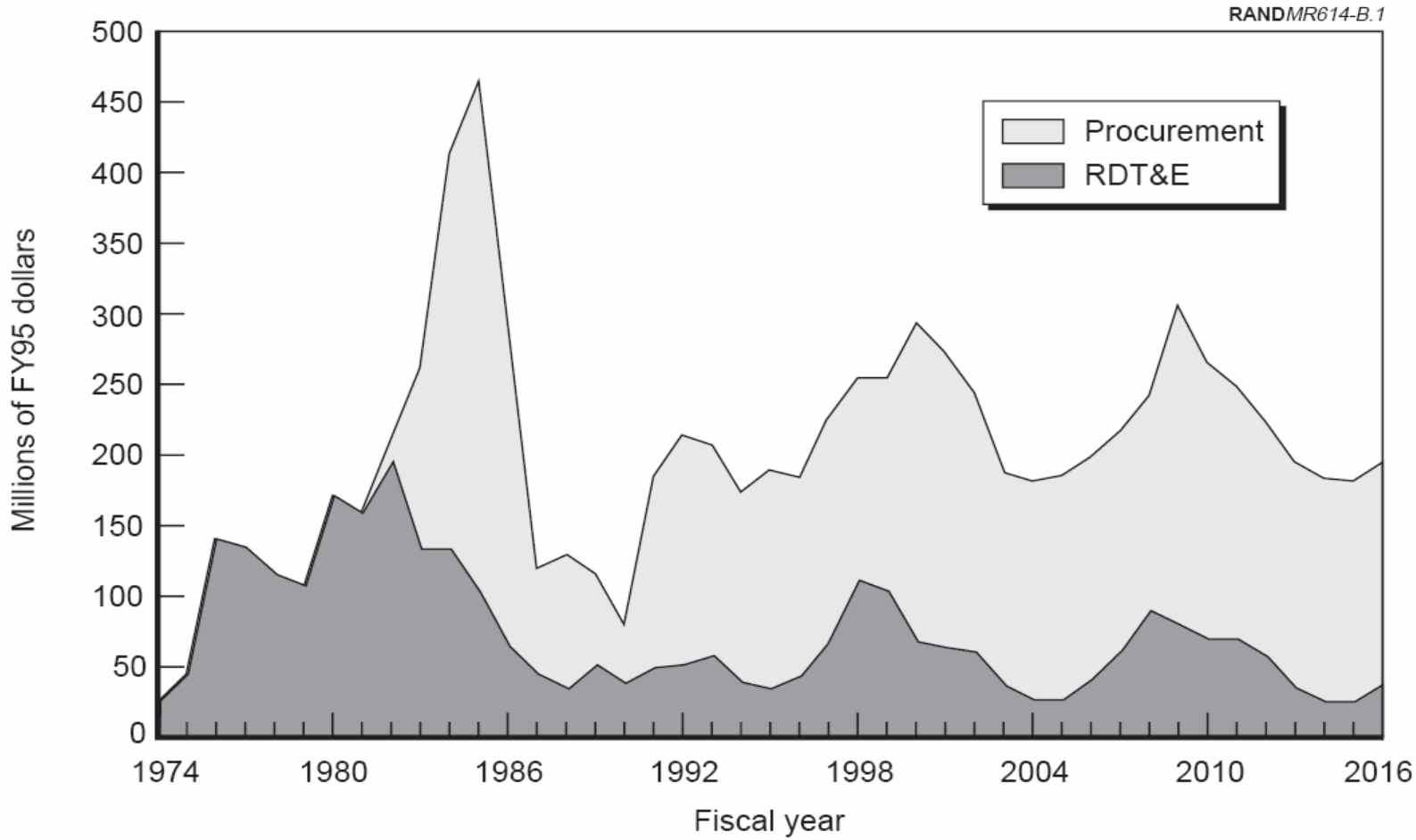
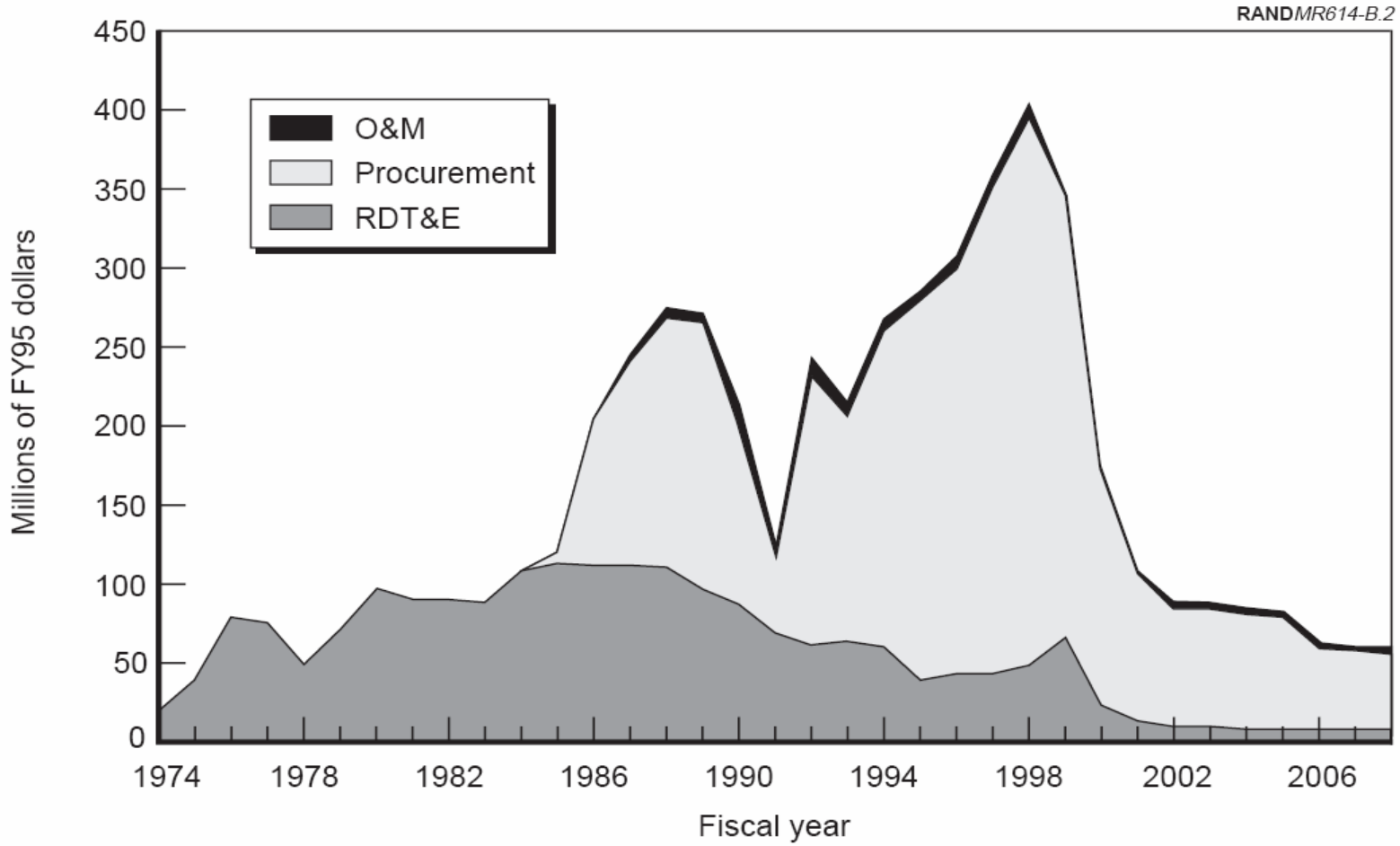
[69] *Selected Acquisition Report* (RCS:DD-COMP(Q&A)823) for the NAVSTAR GPS Program, as of December 31, 1994.



SOURCE: December 1994 *Selected Acquisition Report* (SAR).

Figure B.1—GPS Satellite Costs over Time



SOURCE: December 1994 *Selected Acquisition Report* (SAR).

Figure B.2—GPS User Equipment Costs over Time

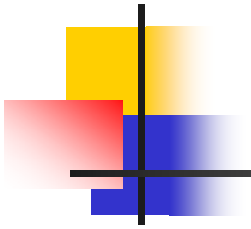
Current eLoran Status

- Loran infrastructure is there
- Excellent research results have been published
- So, now receiver manufacturers should flood the market with high-tech low-cost receivers
- High-tech receivers are available today, but
- Complexity of Loran receivers and costs block low-cost low-power miniature designs necessary for mass markets

Face eLoran Receiver Facts

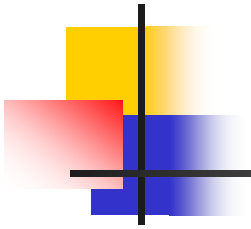
Mass market Loran applications need:

- Low-cost core receiver (<50 $)
- Low power consumption for portables (< 0.2 Watts)
  - μ-blox TIM-LP: 0.3 Watts ☺
  - Loradd SP: 3 Watts ☹
- Small size for portable receiver (< 5 cc)
  - μ-blox TIM-LP: 2 cc, 3 grams ☺
  - Loradd SP: 250 cc, 270 grams ☹
- Small antenna
  - Sarantel quadrifilar helix: 6 cc, 10 grams? ☺
  - Loradd H-field: 500 cc, 400 grams ☹



Costs Challenge

- Current costly receivers based on COTS
  - COTS = components of the shelf
- Low-cost low-power and small receivers need custom-chip design
  - Mobile phones, tracking and tracing of goods
- Large initial investments needed
- Current manufacturers are knowledgeable but cannot afford such investments



Power Challenge

- High dynamic range of received signals (Loran + interference + noise) mandates power-hungry analogue antenna amplifiers
- Multiple chip designs are power-wise less efficient
- Universal applicable DSPs are not optimally suited for Loran signal processing and not very power-efficient
- FPGAs useful solution ??

Antenna Challenge

E-field antenna

- **Pros**:
  - Very small, size only limited by pre-amplifier noise, required sensitivity and occurring back-ground noise/interference
  - Omni directional
  - Basically wide-band providing very low envelope distortion
  - **Low cost**
  - Can be merged with car radio antenna
- **Cons**:
  - Grounding needed
  - Basically wide-band causing interference overload threat

Antenna Challenge, contnd

H-field antenna

- **Pros**
  - Good sensitivity in urban areas
  - No ground needed; can be mounted underneath car
  - Basically band pass response helps to reduce out-of-band interferences
  - Beam steering
  - Compass function
- **Cons**
  - **Costly**, two channels or complex alternating single-channel
  - Less tolerant cycle identification
  - Small size limited by ferrite losses and pre-amplifier noise, required sensitivity and occurring back-ground noise/interference

Mobile H-Field Antenna

Renault Safrane / V6 Gasoline
Loaded with noisy electronics
Relatively low noise antenna position

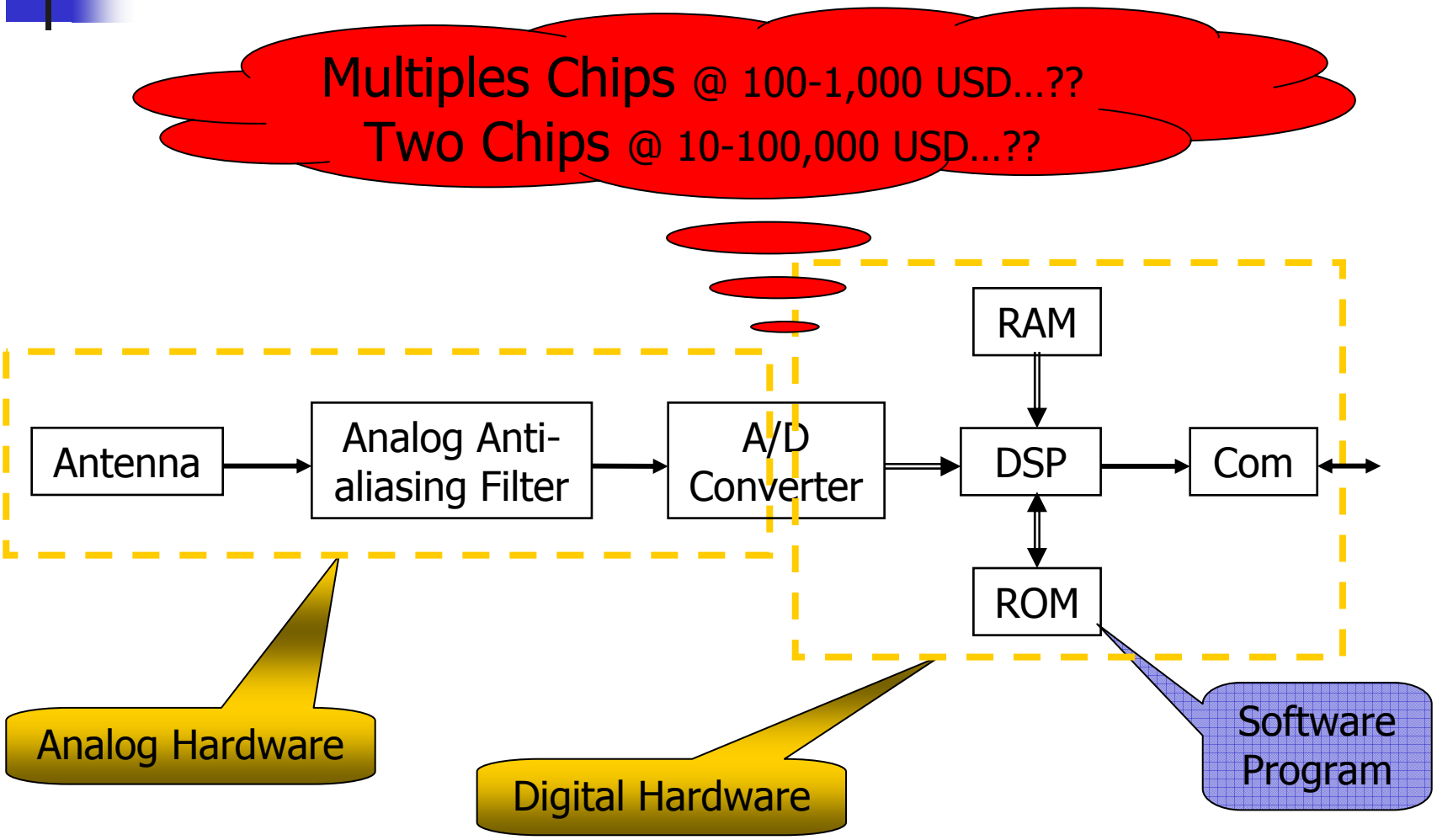
User Challenges

- Over-specifications may jeopardize costs and size of receiver and antenna
- Multiple user groups give multiple sets of specs
  - Accuracy
  - Signal conditions
  - Noise conditions
- But, if Loran is the GNSS backup then it should work when GNSS doesn't, the user says !!!

eLoran Receiver Specs

- Simple to define ☺
- So, designing, developing and manufacturing is no problem ☺
- One single design will not meet specs of all user groups
- How to split user groups and designs?
- **Remember ….** no user-accepted receivers => no users => no eLoran !
- **So, no choice,** we shall be successful …

eLoran Receiver Dilemma



Single-chip Design?

- Only way for mass market Loran applications
  - Mobile phones, tracking and tracing of goods
- Large initial investments needed
- Current manufacturers are knowledgeable but cannot afford such investments
- Joining and co-operating research and development?
- Result must be useful as core for low-end as well for high-end applications of navigation and time

Delft University Example

- Dutch super-yacht builders threatened to lose market to foreign competitors
- Delft was requested for help
- Delft conditionally agreed:
  - Research results were shared with all Dutch yacht builders, pre-competitive
- Technical and commercial results were excellent and Dutch yachts are again world top performers

Useful Approach for Loran?

- Loran receiver manufacturers are multi-national and not national like the Dutch yacht builders
- Governmental bodies (FAA, EU, ESA), user groups and investors prepared for such financing action?
- International Loran industry willing and able to cooperate in sharing risks and revenues?
- How to select members for this group?
- How to avoid that results are going to non-members?

If Then Else…

- **IF** cooperation and/or large capital investment in receiver R&D can be realized
- **THEN** it will speed up eLoran introducing new applications resulting in revenues
- **ELSE** market development will grow slower and continuation of Loran infrastructure remains at risk

Recommendations

- Focus primarily on eLoran receivers as being the weak part of the eLoran chain
- Increase investment in eLoran receiver RDT & E
  - RDT & E = Research Development Test & Evaluation
- Optimize integration of GNSS, eLoran and inertial sensors
- Increase international cooperation

But ….

- All this won’t work as long as eLoran infrastructure is not guaranteed for at least 15 years otherwise industry will not, and cannot invest adequately
- How to convince the policy makers on the northern hemisphere?
  - US/Canada, Europe, Asia, …
- That is our main task now !