# Renewing the Call for a Dedicated Satellite Communication System for Oceanography

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It is time that the oceanographic community become proactive about creating its own dedicated, satellite-communication system. For at least the past decade the community has assumed that emerging commercial systems would fulfill their communications needs, that much larger mass-market, commercial services would offer improved service at lower cost than currently available services. It has not happened.

The lack of practical communications is affecting the ocean community's ability to collect scientific data; crippling efforts at critical improvements in meteorological and climatological forecasting models. For example, the Argo Program is already deploying its world-wide fleet of 3000 drifting buoys without definite communications capabilities that meet its requirements. As a result the program is faced with the possibility of losing critical scientific data.

## State of the Satellite Industry

Commercial satcom systems have not lived up to their hype. Initial delays in deployment were followed by the failure of most to reach operational status. One by one, every satellite-system owner has either dropped out of the business, delayed their operations, or fallen into bankruptcy.

Of the seven original Little LEO licensees (message services), only Orbcomm has fully-operational satellites on orbit. Having emerged from Chapter 11, Orbcomm has never reached their subscriber targets and their future is questionable. Moreover, their system's limited throughput and high cost never suited oceanographic requirements.

The Big LEO licensees (voice services) have fared even worse, taking even longer to come on-line and losing orders of magnitude more money.

Iridium fell into bankruptcy shortly after becoming operational. While the new owners claim sufficient funds to operate for about seven years, it is not clear how much of that depends on reaching new, unrealistic subscriber goals, nor how service might suffer under their new skeleton operations. In addition, reports from users indicate that system reliability is marginal in the harsh maritime environment.

ICO went into bankruptcy shortly after Iridium and has delayed their startup until at least 2007. GlobalStar, which is struggling to emerge from Chapter 11, does not offer service over the deep oceans in any case.

Overall, the state of the satcom industry presents a picture of instability, unreliability, and the inability – or lack of incentive – to respond to the needs of the relatively small oceanographic market.

## Known Oceanographic Projects

It is often argued, erroneously, that the oceanographic market is too small to merit the attention of satcom companies. Our informal survey indicates that there are a number of large projects in oceanography and meteorology that can be readily identified.

Table 1 lists nearly 15,000 known platforms in service or planned. A platform can be a moored buoy, a drifting buoy, a fixed-shore site, or a ship; however, about 75% of deployed buoys are likely to be drifters.

| Program | No. of Platforms |
|---|---|
| Argo Array | 3000 |
| Australia | 20 |
| Brazil | 58 |
| C-MAN Network | 60 |
| DecCen Program | 110 |
| Env. Canada ODAS | 82 |
| GLOBEC | 100 |
| GLOSS | 300 |
| Arctic Programme | 40 |
| IBPIO | 112 |
| IPAB | 20 |
| JGOFS | 10 |
| New Zealand | 18 |
| Netherlands | 19 |
| PIRATA | 12 |
| PSOS | 31 |
| SOOP | 250 |
| South Africa | 48 |
| EGOS | 37 |
| TRITON | 20 |
| TAO | 70 |
| UK Met Office | 162 |
| French Programs | 110 |
| US Programs | 5664 |
| VOS Program | 1000 |
| WOCE | 3414 |
| **Total** | **14767** |

**Table 1, Major International Oceanographic Programs**

In addition to what we have been able to identify, there are many small installations by universities and research institutions around the world, as well as private industrial or military programs that are not publicized. We estimate an addressable market starting at 11,000 units, increasing to 30,000 by 2015.

These are not mass-market numbers; nonetheless, it is a sizeable niche market. Our detailed financial modeling indicates that it would be

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sufficient to support a dedicated satcom system at very affordable prices. In addition, such a system would be able to support many other uses that would not conflict with the oceanographic uses.

### Unique Challenges

Optimizing a satcom system for maritime application means balancing the constraints imposed by ocean-data collection systems against those imposed by the satellite constellation.

Noise in the marine environment affects radio communications in fundamental ways. The ocean-to-satellite RF link can be subject to several sources of signal degradation not faced by terrestrial systems:

- Antenna wash-over
- Ground-plane variations
- Water aerosols
- Wave obscuring
- Ocean-surface roughness

Effective mitigation of these issues requires close attention to low-level communication protocols. This key issue is not addressed by any existing or planned satellite systems.

Power is the most limited commodity for virtually all ocean-data collection platforms. The communications power budget is typically set at 10% of the total available, but the amount of data return is more often determined by the limitations of available satcom throughput rather than the needs of the research. While power availability also limits, to some extent, sensor sample rates, most platforms can collect much more data than they are able to return over existing satcom links.

Drifting buoys pose the worst case for satcom systems due to their size, power budget, and operational profile. Nevertheless, modern drifters have ample capacity to exploit much higher throughput satcom links, if they were available.

Designing and operating a satcom system to provide real-time communications is prohibitively expensive. Meteorology has the most stringent timeliness requirement: data must be less than 3 hours old, as close to real-time as possible. An overall latency of close to 1 hour is the optimal trade-off between cost and timeliness.

Every satcom system has limits to the number of simultaneous users it can accommodated. In oceanography, users are widely disbursed across the world and the average density is very low. However, many individual programs tend to deploy platforms in clusters. While it is clear that a dedicated oceanographic satcom would be underutilized in many areas of the world, it must be designed to accommodate relatively dense clusters of users in other areas.

### Constellation Requirements

A satcom network designed for oceanography must be scalable to meet capacity requirements and potential growth, rather than requiring a fixed number of initial satellites in order to be operational. It must be planned strategically as a sustainable system that will remain viable beyond the projected life of any particular program.

Minimum requirements for a new satellite constellation devoted to oceanographic data transmission include:

- 1 Mbyte or more data per platform per day
- Low user fees
- Antennas < 20 cm high
- Power use < 0.05 J/bit
- < 1-hour system latency
- Variable data rates

To minimize power requirements on the platforms, the satellites must generate strong signals and detect weak signals. To maximize global coverage, the satellites should be primarily, but not exclusively, in high-inclination orbits. Orbital altitude is a trade-off between larger footprints and longer view periods with higher altitude, but at the cost of increased transmit power and receive sensitivity.

The optimum satellite-link frequencies are a trade-off between smaller antennas at higher frequencies and lower free space loss at lower frequencies. For example, while a 5/8-wave whip antenna at 150 MHz is just over 4 feet long, an antenna of equal gain at 2 GHz is only 3.7 inches high. Even the smallest oceanographic platforms could easily accommodate such an antenna at 2GHz. However, a 2-GHz system would need to provide 27 dB more link margin for equivalent signal strengths. A large satellite would be capable of making up this deficit with larger antennas and higher power transmitters.

### Constellation Concepts

Many factors come into play when considering the optimum satellite constellation for oceanography. Microsats in LEO orbits are commonly suggested as an optimum solution, primarily due to their low cost. However, this solution has severe limitations.

Microsats cannot support large solar panels, batteries, or antennas, therefore they must be in lower Earth orbits. Even then, a microsat will not be able to generate sufficient RF power to achieve desirably high data rates. Users will be limited to lower data rates and larger, higher power communications equipment.

Larger satellites can generate stronger signals that accommodate higher data rates; user equipment can be smaller. Larger satellites can also support larger receive antennas that provide the gain needed to hear weak signals from less powerful transmitters.

A great advantage of geostationary orbiting satellite (GEO) systems is that they provide near global coverage with as few as 3 satellites. Operating in a bent-pipe mode – frequency shifting and retransmitting any signal they receive – they are very flexible in operation. However, the required GEO altitude of 35,786 km requires large power systems, and costly launches for orbital insertion. Also, geostationary orbits must be equatorial, so the satellites cannot provide service to high-latitude users.

A good compromise would be large satellites in medium Earth orbits (MEO). If a satellite is positioned at half the distance to a GEO orbit, signal levels would be maintained with only 1/4 the power.

While the footprint of a LEO satellite is about 3,000 km, the footprint from a MEO satellite is 10,000 km, more than enough to span the oceans. This makes possible the use of bent-pipe mode of communications. MEO satellites can be place in high-inclination orbits to reach polar users. Global real-time coverage can be attained with as few as 6 satellites

A single satellite in a MEO orbit has an orbital period of about 6 hours; three visible passes of 2.5 hours/day provides 7 hours/day of link time. A single LEO satellite provides about 1 hour/day of usable link time in 4 passes of 15 minutes each. Thus, one MEO satellite can provide the same link-time coverage as seven LEO satellites. A bent-pipe MEO satellite can also significantly reduce the store-and-forward latency of a LEO store-and-forward latency of a LEO satellite from as much as 14 hours to only 4 or 5 hours, the time a user might wait for the MEO satellite to become visible.

A constellation of MEO bent-pipe satellites can be put into initial service with just one satellite and one network groundstation to provide a regional service. As few as five groundstations strategically located around the world, allow that one satellite can provide global service, albeit with an unacceptable latency for meteorology.

Such a service might best be referred to as “scheduled real time.” A platform would be able to use the satellite whenever both the platform and a network groundstation are in the same footprint. Depending on orbital inclination, this can happen for between one hour/day to as much as 6 hours/day. During times of co-visibility, a real-time connection could be established with the platform.

## Conclusion

Understanding global climate change has become an international priority. The lack of the tools to collect the needed data has developed into an emergency situation. The ocean community can no longer maintain their wait-and-see attitude. The extensive problems with the very underpinnings of existing commercial satellite systems makes it eminently clear that the community must find a way to meet their own communications needs. The market is large enough to support its own system; the means to create it must come from the collective will of the community.

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