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MEMORANDUM

To: Brad Orr  
From: Mike Reynolds  
Subject:

December 3, 2011  
File: M1111-4

**Magic Leg0 Instrumentation Ideas**

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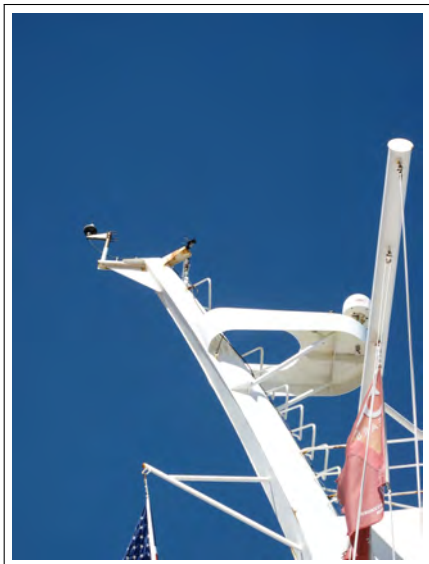
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**About the Leg0 Cruise.**

I am quite interested in moving as quickly as possible on whatever instruments we decide to use for the Leg0 cruise. There are many different ways to resolve the needed measurements and the ones here are just one solution. The designs here were selected because they all involve known instrumentation and electronics with many components on hand. Further, software for these instruments either already exists or can be quickly created from similar code in other systems.

**Meteorological System**

The purpose of the meteorological system for Leg0 is to get some idea of the wind sheltering and flow distortion we would encounter under typical operation. A meteorological system that is presented here can be mounted on the top deck of the ship mast with a junction box that links the instruments to the laptop data acquisition computer on the bridge.



**Figure 1: Mast Platform**

The SPIRIT has a fairly unencumbered main mast. It is well forward and nicely exposed. There should be minimal wind flow distortion here. We propose to mount a long cross beam on this platform with a WXT weather sensor at each end. The beam can be mounted without need for drilling or welding. It will be schedule 80, 1" pipe by 3 m long and will use scaffolding clamps and some special machined parts for the clamps. While in port the two WXT's can be placed side-by-side to confirm their calibrations.

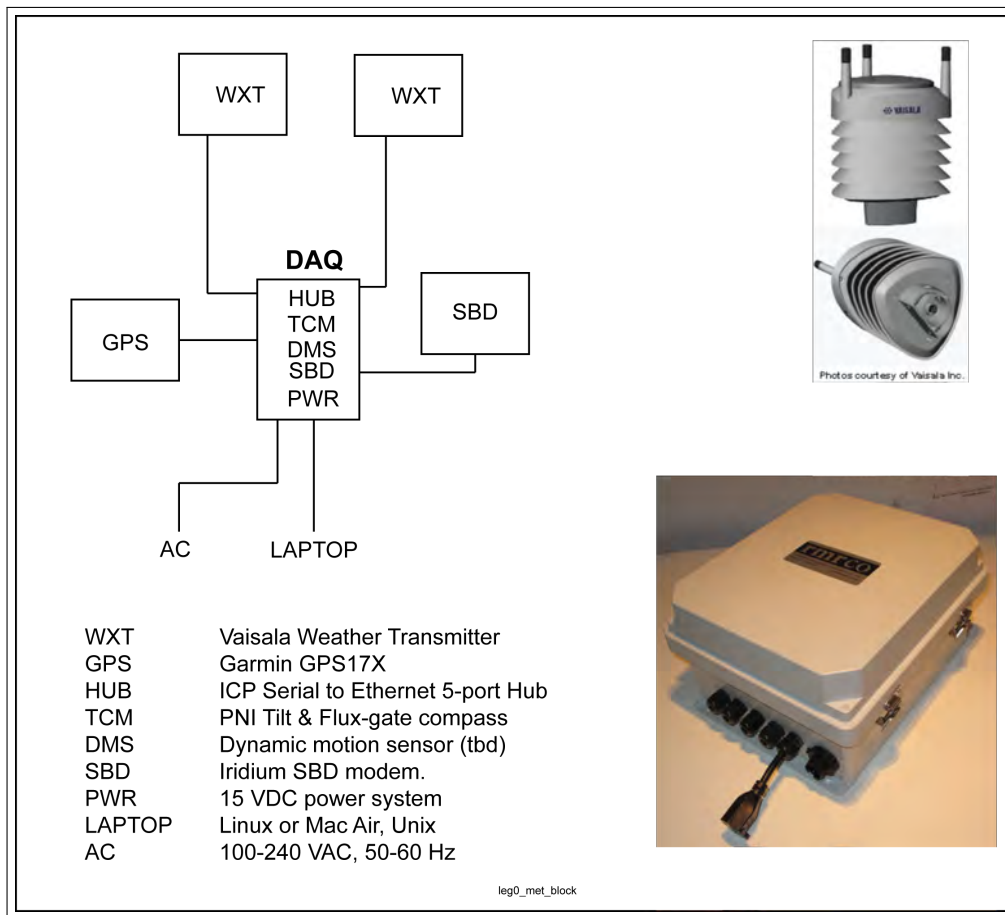


Figure 2: Leg0 Met Block Diagram.

Figure ?? outlines a data acquisition system (DAQ) that can be mounted at the same level and has an Ethernet connection to a computer on the bridge.

The WXT sensor is an all-in-one weather station. It has a 2-D sonic anemometer, barometer, RH sensor, air temperature sensor, and a rain gauge. We have tested this in many at-sea applications and found it to be an excellent, highly accurate instrument. It can be heated but this is not a problem for MAGIC. The units can operate in many different sampling modes, but for a ship use it is best to have each unit send 1-second raw measurements to a data logger device. In this way the GPS and DMS heading data can be combined with apparent winds to compute real-time true wind calculations. The final data product would be a record of two-minute vector and scalar averaged data. All raw data are recorded as a matter of course. A good choice for Dynamic Measurement System (DMS) is the Watson DMS-SGP02. Cost, I think, about \$10000 which includes software for deriving instantaneous true rotational measurements at 4 Hz. It has RS232 data connection which works well with the HUB design.

The leg0 met system DAQ integrates two WXT sensors, a GPS, tilt-compass sensor, DMS, and Iridium SBD telemetry into a single small (300 x 500 mm) waterproof enclosure. The system runs off of AC power and has a single Ethernet connection to all sensors. Note that it is possible for an operator to review and interact with any sensor without interrupting overall data flow. The SBD data message will provide a half hourly update on data quality, ship location, and motion. SBD messaging runs about \$250 per month.

Major expenditures for this system are as follows:

1. Two WXT sensors at \$2800 each, 2. GPS17X at \$290. 3. NAL SBD modem and antenna. \$700. 4. DMS Motion sensor. \$10000. 5. DAQ computer, software and hardware, \$1200. 6. Misc mechanical: junction box, plugs, cables and wires, \$400. 7. ICP Hub, power supply, network switch \$500.

A very rough estimate for these parts then is \$17000. Technical support labor–machine shop, electrical assembly will add possibly \$3000 to that. Thus a complete mast mounted met system can be fabricated for a cost of approximately \$22K. Considering this system has Iridium telemetry and a high quality dynamic measurement system, this is not too bad a price.

Of course this DAQ system can remain for the complete MAGIC program. In fact it is reasonable to leave it installed permanently for the rest of the year and after the beginning of the MAGIC cruises. It can be the backbone of the MAGIC mast measurements.

The dynamic measurement system that was selected for the AMF2, per Rich Coulter, is the Kerflott SeaNav, a monolithic ring laser gyro inertial quality pointing, stabilization, survey, and navigation device (see brochure below). This will be mounted approximately 30 m above the sea surface. The ship center of buoyancy will be near the water line, so pitch and roll motions will produce strong lateral accelerations. The SeaNav will be able to separate the rotational and linear accelerations and will produce quality ship motion data.

Other, less expensive, dynamic measurement sensors (DMS) use accelerometers to compute tilt. It is difficult to compute the pitch and roll because of the complex motions away from the center of buoyancy. We need to have a good look at the DMS needs and be sure we can compute or measure the correct motion terms for the instruments deployed.

## Faux Radiosondes

The wind flow around the ship superstructure can cause problems with balloon launches. To avoid collisions with ship structure the balloon is launched from a lee rail. If the downdraft is too large or the balloon ascent rate is too low, there is a chance the balloon payload will strike the sea surface. We will launch balloons: either from the aft fantail of the ship, into the slip stream behind the ship or on the bridge deck. The bridge deck is forward, and conveniently located with the instrument vans. From this location we would be assured of good radio reception during the crucial first minutes of the launch. The bridge deck is our first choice for a launch site.

Balloon systems include a pay-out spool that increases the tether length in the first minutes of the launch. If the pay-out is too rapid and the balloon is in a downdraft, then an ocean dunk is possible.



Figure 3: Sonde Launching.

The balloon systems, with faux sondes, will be launched from several areas on the ship. The launch location will depend on wind speed and direction and how the winds blow over the ship. We will prefer launching from the bridge deck but if that is a problem we'll try launches from the aft fan tail area at the very rear of the ship.

We will launch (say) twelve (12) test balloons with dummy payloads. This would require three cylinders of He, balloons, parachutes, pay-out spools, and a dummy payload. The dummy payload could be made of a water balloon, sand-filled paper bag, or other, hopefully biodegradable, design.

Equipment includes: 1. Cylinders, 12 ea, 2. Inflation tools, regulators, weights. 3. Portable shelter for wind protection. 4. Launch gear such as string, spool, reflector, faux sonde, parachute. 5. Video camera (iPhone?) for each launch.

## Sea Surface Temperature

The Infrared Sea-Surface Temperature Autonomous Radiometer (ISAR) is designed to operate autonomously for four months and maintain a temperature accuracy of 0.1°C. It has proven this specification on numerous intercomparison experiments. The instrument is fabricated at the National Institute of Oceanography, Southampton (NOS) to RMR Co. specifications. RMR Co. provides data acquisition electronics, calibrations, and maintenance.

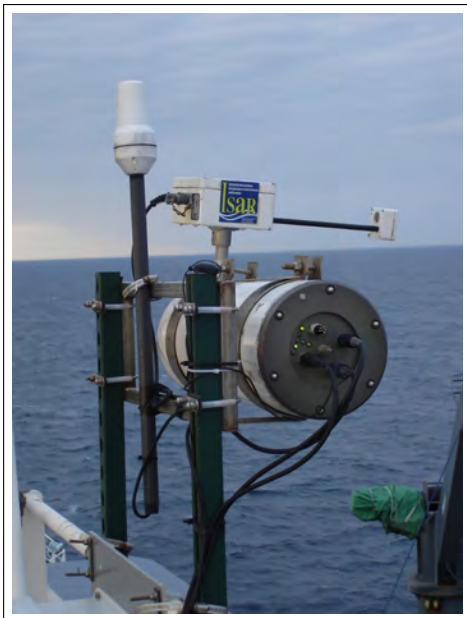


Figure 4: **The ISAR on a ship railing.**

The ISAR mounts on a ship rail in a forward location so that it can point to the sea surface ahead of the ship wake. The pointing angle might be 45–55° but in some occasions angles as small as 25° have been used. The pointing angle (measured from nadir) likes to be as small as possible to minimize surface reflection of energy from the sky.

The data acquisition (DAQ) box is mounted nearby. The optical rain gauge, GPS, and Iridium antenna are attached to the frame.

Currently, two ISAR instruments are deployed on a commercial car carrier as part of a NASA satellite validation program. This project is managed from the University of Miami under Prof. Peter Minnett. RMR Co. is in charge of the maintenance, data collection, and deployment. One ISAR instrument is always on the car carrier as it travels between Japan and the U.S. The instrument operates for four months before it is replaced by the spare. During any deployment the spare unit is refurbished and calibrated. In December the spare ISAR will be deployed for two weeks on a scientific cruise from Samoa to Hawaii. It will return to Seattle on about 19 December. It is not scheduled to be deployed on the car carrier until February and thus it is available for the Leg0 cruise.

We will make a request to Univ. of Miami for a loan of the instrument for Leg0. I expect this request to be approved as long as the car carrier program is not compromised. In fact, as a validation program, more data are all to the good.

## SEABORNE NAVIGATION SYSTEM (SEANAV)



The Seaborne Navigation System (SEANAV) hardware is fully qualified for at-sea operation and is the latest addition to Kearfott's family of Monolithic Ring Laser Gyro (MRLG) based inertial quality pointing, stabilization, survey, and navigation devices for maritime applications. The SEANAV modular architecture provides maximum flexibility, offering selectable performance and future upgradability. A sophisticated Kalman filter allows for aiding from various onboard devices such as GPS, Sonar/Doppler, Speed Log Aid and Screwspeed. Typical applications include surface and subsurface vessels, remotely operated vehicles, and autonomously operated research/survey vehicles.

**GPS Receivers** - The SEANAV system is designed to accommodate either an embedded (-G) or an external GPS receiver. Integrated systems presently available include:

- GPS Embedded Module - C/A Code or P(Y) Code
- Precision Lightweight GPS Receiver (PLGR) with differential capability - C/A, P(Y) Code or Defense
- Advanced GPS Receiver (DAGR) P(Y) Code
- Selective Stand Alone GPS Receiver - C/A , P(Y) Code or differential

**SEANAV features include:**

- Multiple I/O (RS-422, RS-232)
- Multiple Output Formats (Geodetic)
- At sea align capable with GPS aiding
- Interfaces with P(Y) or C/A code GPS for alignment & aided navigation
- Interfaces with Sonar/Doppler and/or Speed Log for aided navigation
- Custom displays can be provided to accommodate unique customer requirements



## Dynamic Measurement System with Dual Antenna GPS

### DMS-SGP02

#### **Description:**

The DMS-SGP02 is a miniaturized version of the DMS-EGP02. To allow for a smaller package, the DMS-SGP02 uses our S series MEMS rate gyro.

The DMS may be used in almost any application where triaxial angular rate and acceleration data is required. The sensor provides both angular rate and acceleration outputs in analog and digital formats. The DMS features six accelerometer

outputs. The X, Y, and Z axis outputs represent the accelerations in the plane of the vehicle body, while the second set of three outputs measure the acceleration aligned with an earth-level coordinate system. This allows forward and lateral acceleration measurements that are essentially free of gravity influences. The triaxial sensor set allows software alignment of sensors, greatly reducing any alignment errors. The serial interface is highly configurable and provides access to almost all operational parameters.

The DMS-SGP02 is designed to be used in vehicle applications where accurate heading is required, but a magnetic compass is infeasible. This sensor is equipped with a dual GPS antenna system that provides heading data even when the vehicle is not in motion. The addition of the GPS antennas also gives vehicle velocity data to the DMS that enhances the unit's performance during highly dynamic maneuvers such as sharp turns. This makes the DMS-SGP02 inertial gyro sensor a more complete system since it does not require velocity information to be supplied from an external sensor. An antenna spacing of 0.500 meters  $\pm 5$ mm is required.

- Solid State, Strap Down System
- GPS Heading Reference
- Low Cost
- Rugged, High Reliability
- Vibration Resistant
- Analog and RS-232 Serial Outputs
- One Year Limited Warranty
- Engineering Support



#### **Applications:**

The DMS-SGP02 is useful in automotive testing, vehicle dynamics, marine and aircraft applications. This sensor is most useful in applications where strong magnetic fields make heading data from a fluxgate magnetometer unreliable.



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