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THE MOBILE INTEGRATED SOUNDING SYSTEM (MISS): DESCRIPTION AND LESSONS FROM THE SIERRA ROTORS PROJECT

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1. INTRODUCTION

The Mobile Integrated Sounding System (MISS; Fig 1) uses a boundary layer radar wind profiler with RASS (Radio Acoustic Sounding System) to measure wind and temperature in the lowest few km with 30-min resolution, and a GPS rawinsonde system to measure wind and thermodynamic variables into the stratosphere. Tower-based surface measurements are also made to anchor the wind and thermodynamic profiles and to measure shortwave and longwave radiation. Instruments used are the same as those of the Integrated Sounding System (ISS; Parsons et al. 1994), but with the ability to move more quickly between locations.

The ISS web page (http://www.atd.ucar.edu/rtf/facilities/iss/iss.html). summarizes the capabilities and limitations of the instruments. MISS, as a modified ISS, is one of the NSF Lower Atmospheric Observing Systems and is available to researchers through the observing facility request process described at http://www.atd.ucar.edu/requests.html.

MISS has been described by Cohn et al. (2004a), including preliminary results from a field test in eastern Colorado. The first NSF deployment of MISS was the Sierra Rotors Project (SRP) in March-April 2004 in Owens Valley, California. SRP is a study of atmospheric rotors designed to establish quantitative characteristics of the rotor behavior in the lee of the Sierra Nevada including the rotor type, location and the frequency distribution of the related mountain-wave events, and to determine the extent to which current operational mesoscale models can reliably forecast the occurrence of rotors. It is lead by the Desert Research Institute, in collaboration with the Naval Research Laboratory, University of Washington, and NCAR. In addition to MISS, a standard ISS, a network of surface sensors, two upwind special rawinsonde systems (one mobile), and other assorted sensors collected observations. SRP is described in Grubišić and Kuettner (2005) and Grubišić and Cohn (2004).

This paper describes the MISS participation in SRP, including observations and lessons for future deployments.

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2. MISS INSTRUMENTS AND OPERATIONS

MISS consists of a camper on a pick-up truck, and a flat trailer pulled by the truck, on which the wind profiler antenna is mounted. The camper contains computers and laboratory equipment; some external sensors are stored in the camper while MISS is in transit. MISS does not make measurements while moving.

Half-hourly wind profiles are measured with a standard Doppler Beam Swinging (DBS) boundary-layer radar wind profiler (e.g. Carter et al. 1995). A unique clutter screen which folds during transport is also used. With a consensus-averaging period of 30 min. (configurable), and a 15-30 min. setup period, the first wind profile represents a period from approximately 15-45 min. after arrival at the site, and is generated within the first hour. A shorter averaging period and the NIMA/NWCA algorithms have been used to post-process SRP data, providing 10-min winds. NIMA/NWCA use fuzzy logic and global image processing to find moments and vector winds from Doppler spectra. The algorithms are described in Morse et al. (2002) and Goodrich et al. (2002), with a validation exercise described in Cohn et al. (2001b).

The Radio Acoustic Sounding System (RASS) is operated for approximately 5-min. of every half-hour. RASS uses the DBS wind profiler with upward propagating sound waves to measure profiles of virtual temperature.

Upon arrival at a measurement site the wind profiler antenna is leveled, cables connected, clutter screen is assembled, and RASS acoustic speakers are deployed. Once a flux-gate compass determines the antenna orientation, profiler and RASS operations can begin.

During SRP MISS used a Mobile GLASS (now called GAUS) rawinsonde system (http://www.atd.ucar.edu/rtf/facilities/iss/iss.html) with Vaisala RS-80H rawinsondes. This system can be setup and a rawinsonde released in about 15-min. Project priorities determine whether the wind profiler or sounding system is setup first.

A 10-m surface tower is assembled to collect measurements at WMO (World Meteorological Organization) standard heights. The surface sensors include temperature (T) and relative humidity (RH) at 2-m, wind speed and direction at 10-m, and solar sensors for direct downwelling visible and direct downwelling infrared radiation (PSP, PIR). These radiation sensors are mounted on the roof of the camper. A net radiation measurement is not currently made from the camper because the downward field-of-view is blocked by the equipment. The nominal deployment plan is for MISS to

Figure 1: Mobile Integrated Sounding System during the Sierra Rotors Project. The truck and camper are at left (with MotoSat communications antenna and net radiation sensors on the camper roof), the trailer with wind profiler antenna and clutter screen at center (small dishes between are the RASS acoustic source/reflectors), and the 10-m surface tower is at right. The Inyo Mountains east of Owens Valley are in the background.

travel to a site, collect data for a period of several hours to several days, and then move to another site. For SRP a MISS base site was used along with several remote sites. The base site had access to line power and allowed MISS to operate continuously. In advance of some intensive operations periods (IOP), and based on rotor event forecasts, MISS was moved to one of the remote sites. These were scouted well in advance. At a remote site MISS operated on its small generator which must be refueled approximately every 12-h.

During SRP the setup time for MISS varied from 45-90 min. as more experience was gained by the crew. During development of MISS, a design goal was that all equipment would be deployed within 15 minutes of arriving at a suitable site, but several (costly) future upgrades will be needed to achieve the 15-minute goal. Also, setup time will naturally vary because of site and weather conditions. MISS requires two or three operators for setup, teardown, and normal operations, and for extended IOP a second shift may be required.

MISS data was made available on a remote web site using a Mobile Internet satellite system (MotoSat) whose antenna is mounted atop the camper.

The MISS concept has much in common with the University of Alabama Mobile Integrated Profiling System (MIPS; http://vortex.nsstc.uah.edu/mips/). Both extend the flexibility of atmospheric wind profiling with some differences in instruments and usage.

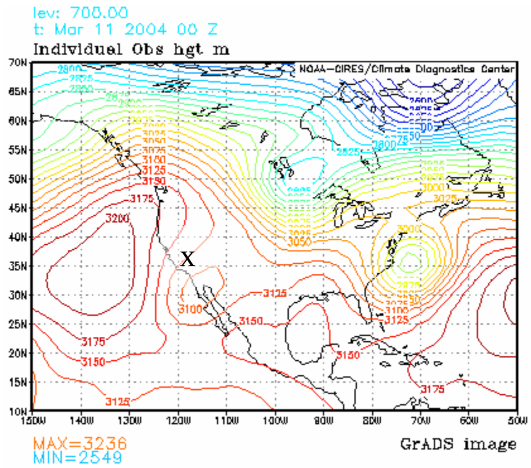

Figure 2: 700 hPa heights at 00 UTC 11 Mar. 2004. The location of SRP is indicated with an X. (NCEP/NCAR reanalysis, provided by the NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, from their Web site at http://www.cdc.noaa.gov/)

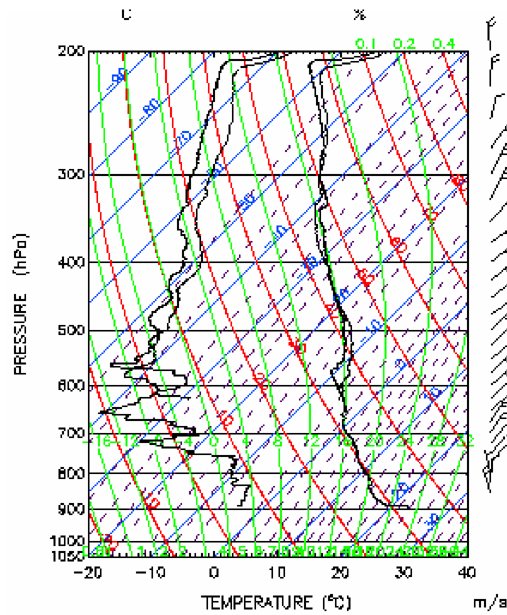

Figure 3: Skew-T of the MISS sounding launched at 1930 UTC. Wind barbs at right are in m s^{-1}.

3. MISS ACTIVITY DURING SRP IOP#2

Data provided by MISS and the ISS/MAPR were intended to characterize the local boundary layer continuously (wind profiler and surface station) and the free troposphere and lower stratosphere during IOPs (rawinsonde). The MISS and MAPR wind profilers were also being evaluated as tools to diagnose mountain waves and rotors. In particular, the vertical velocity measured with the profiler vertical beam could diagnose the presence of waves, and broad width of the Doppler spectra could indicate velocity variance from turbulence. These topics are discussed in Brown et al. (2005) and Grubišić and Cohn (2004), in which SRP IOP#8 is examined. Here we present MISS measurements from IOP#2.

IOP#2 of SRP took place from 1930 UTC on Mar. 10 through 02 UTC Mar. 11, 2004. The 700 hPa heights at 00 UTC Mar. 11 (Fig. 2) show a high off the central California coast and a weak trough extended to the east and south of Owens Valley. Most wave and rotor events in the Valley occur with strong westerlies over the Sierra Nevada to the west of the valley. However, the synoptic setting on this day brought moderately strong easterlies over the Inyo Mountains to the east. In anticipation of wave activity in the lee of the Inyo Mountains, MISS was deployed the prior evening to the "East Valley Site", a previously scouted location on the east side of the Valley. MISS is not used unattended unless at a secure base site, so it was not operated overnight. Plans were made to begin collecting data at 21 UTC the next day (PST = UTC – 8). However, the winds at mountaintop height increased and became easterly considerably ahead of the forecast time. The MISS wind profiler was started shortly after 19 UTC, with the event already in progress, and soundings were launched at 1930 and 2130 UTC. Figure 3 shows the 1930 UTC (11:30 PST) MISS sounding Skew-T. The atmosphere is very dry throughout the troposphere with RH near 20% in the boundary layer and less than 10% above. There is a weak inversion at 830 hPa and a stable layer from 700 to 480 hPa. The double trace appears because this sounding was also tracked as it fell after the balloon burst. The descending profile is very similar to the ascent, and in fact due to a coincidence of the wind profile, this sounding fell to earth less than 5 km from its launch point. The winds from this sounding are shown on the right of Fig. 3. The lowest winds are from the NNW, approximately aligned with the Owens Valley down-valley flow direction, and consistent with the surface winds measured by the DRI anemometer network (Fig. 4). Winds above 800 hPa quickly turn to be from the NE and strengthen with height. To generate waves, in addition to the identified stable layer, winds near the Inyo Mountains tops (~3,000 m) should be more closely perpendicular to the ridgeline (optimal direction is ENE) with strength of at least 15 m s^{-1}.

The radar wind profiler is the centerpiece of MISS. Figure 5 shows 30-min. wind profiles collected during IOP#2. At the East Valley site winds below about 500 m AGL were contaminated by clutter. However, down-valley winds are seen from 500 m to about 1 km. Winds above the valley are initially greater than 12 m s^{-1} from the NE (the forecast easterly flow had already begun) and as the IOP continues they weaken and rotate to be more northerly. Although Fig. 3 shows the atmosphere above Owens Valley is already quite dry, the 2130 UTC sounding (not shown) shows even further drying of the air at 1.5 km AGL. This explains the eventual low signal strength and resulting lack of profiler wind measurements after 23 UTC. By 02 UTC on Mar. 11 (18 PST) it was clear that the winds aloft no longer had a strong cross barrier (ENE) component, and IOP#2 was ended.

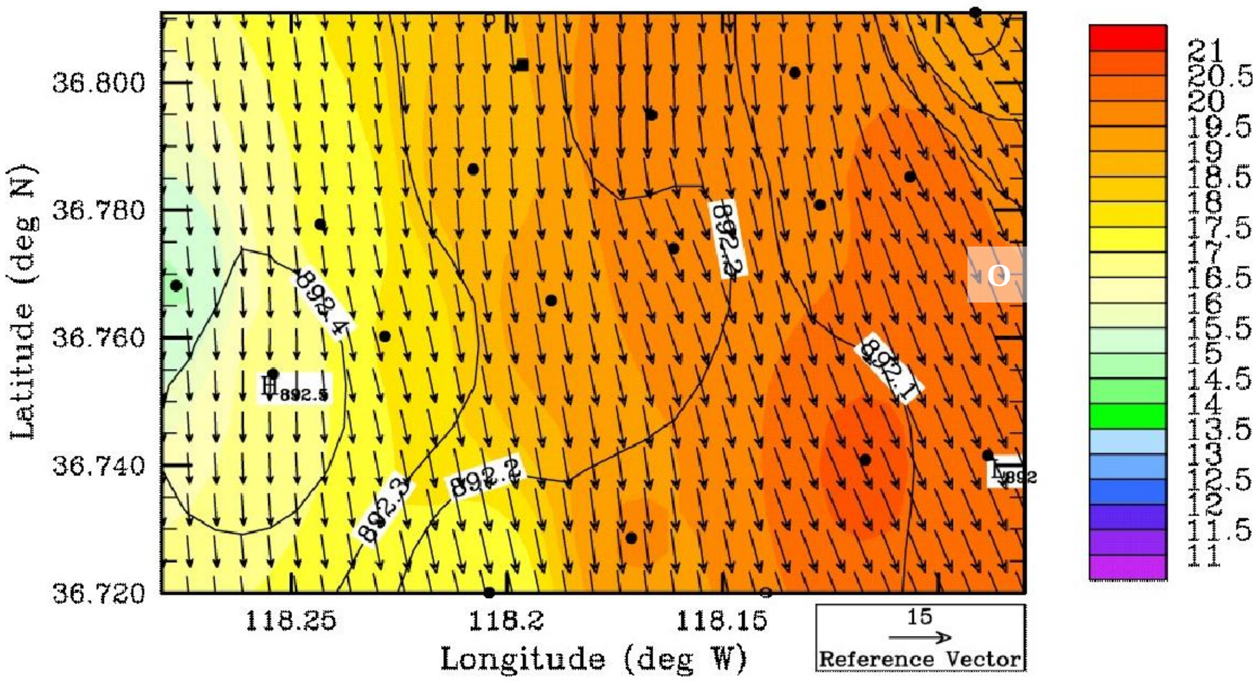

Figure 4: Vector winds (m s^{-1}), temperature (^{o}C, color), and pressure corrected for the valley slope (hPa, contours) at 19 UTC on Mar. 10. There is a well established down-valley (NNW) flow. The MISS site is indicated by the white circle (right side), and black dots are the sites of the DRI surface (automatic weather station) network.

The profiler vertical winds and Doppler spectral width during the early part of the IOP are shown Fig. 6. During this time, MISS measured many episodes of vertical winds greater than 2 m s^{-1} (both upward and downward). This suggests that weak gravity waves were orographically produced by the ENE flow. Over the same period the measured Doppler spectral widths were generally less than 2.5 m s^{-1}, with occasionally higher values. These widths were corrected for the broadening effects of finite beamwidth and wind shear (discussed, for example, by Nastrom, 1997), but widths of this magnitude probably do not indicate the large turbulence which would be expected during a strong mountain wave, and especially a rotor event.

5. LESSONS AND FUTURE PLANS

MISS was quite successful in contributing to SRP. With minor exceptions the instruments were working properly and operated at the times and locations planned for each IOP. Investigation into the use of vertical wind and Doppler spectral width to diagnose waves and turbulence associated with rotors is continuing, as is the analysis of measurements and model forecasts for all SRP IOPs. Several lessons stood out in an evaluation following the project.

1. The time and effort to set up MISS was greater than desired. Design changes, for example to make the surface tower easier to assemble, the clutter screen assembly more convenient, or automate the process of leveling the antenna, are possible but costly. Other compromises are possible, for example using a simpler surface tower for deployments where WMO heights and precision are not required.
2. MISS was not designed for use on rough (rutted dirt) roads. Even with cautious driving some equipment damage did occur. The trailer suspension will be strengthened before the next deployment. This will prevent future damage, but MISS is still not an “off-road” system.
3. Advance planning, including use of a MISS base site with power and pre-scouting of usable sites throughout the Owens Valley, was quite valuable. This saved time searching for a suitable site immediately before setup and ensured a site with the best ground-clutter blocking. While advance scouting will not be possible for every project, when it is, the experimental goals will be better met.
4. During SRP MISS was often setup the day before an IOP based on model forecasts of the upcoming event. For a first experiment it was reasonable to plan for a less demanding schedule. However, on more than one occasion, including IOP#2, changes in the forecast complicated operations. The lesson is to retain as much deployment flexibility as possible and try to be prepared for changes – especially operations earlier than scheduled.
5. Sensitivity and altitude coverage was limited in Owens Valley due to the low humidity. The MISS wind profiler is a commercially available product (Vaisala LAP-3000) and any such system would face the same challenge. This problem can only be addressed by developing new wind profiler technology.

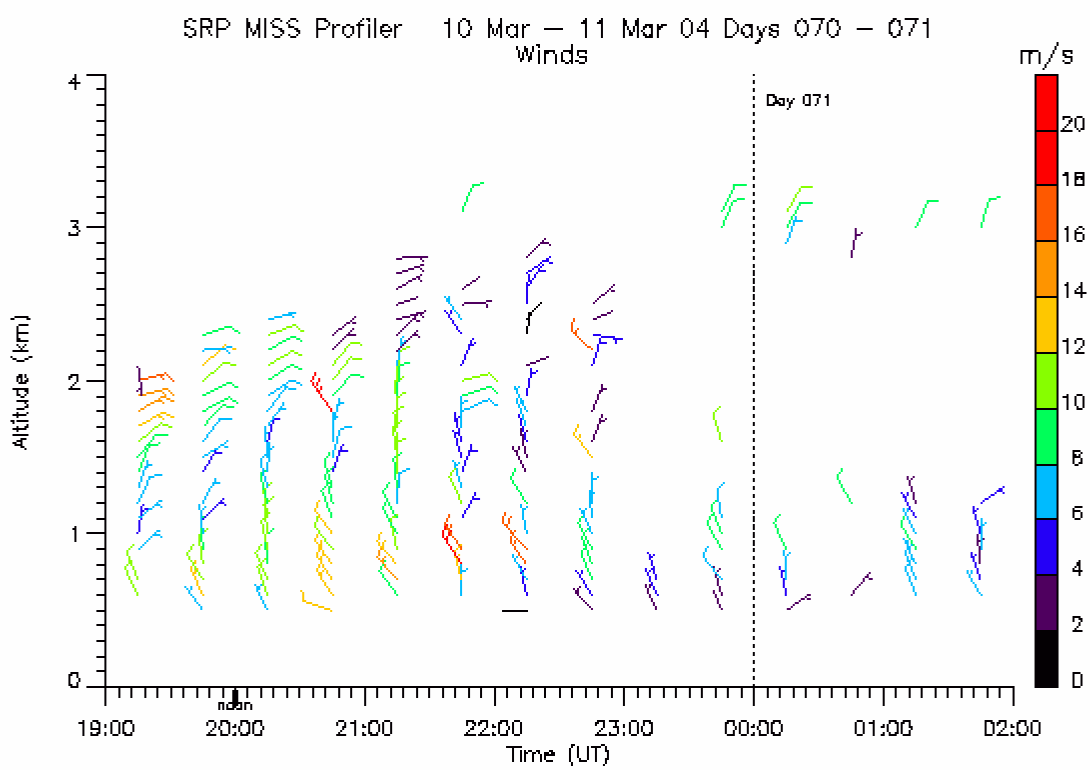

Figure 5: Half-hour MISS winds (barbs; m s^{-1}) from 19:15 UTC on Mar 10 through 02 UTC on Mar 11.

6. Contamination of winds by bird clutter was a minor problem during this experiment. As with any DBS boundary layer wind profiler, the intermittent clutter removal algorithm (ICRA) was turned on so only periods with high bird density were affected. Again, this is a problem which is not unique to MISS.

MISS has been requested for the Terrain-induced Rotor Experiment (T-REX; Grubišić and Kuettner 2005) in 2006. It is expected that these lessons learned during SRP will contribute to an even more successful deployment for T-REX.

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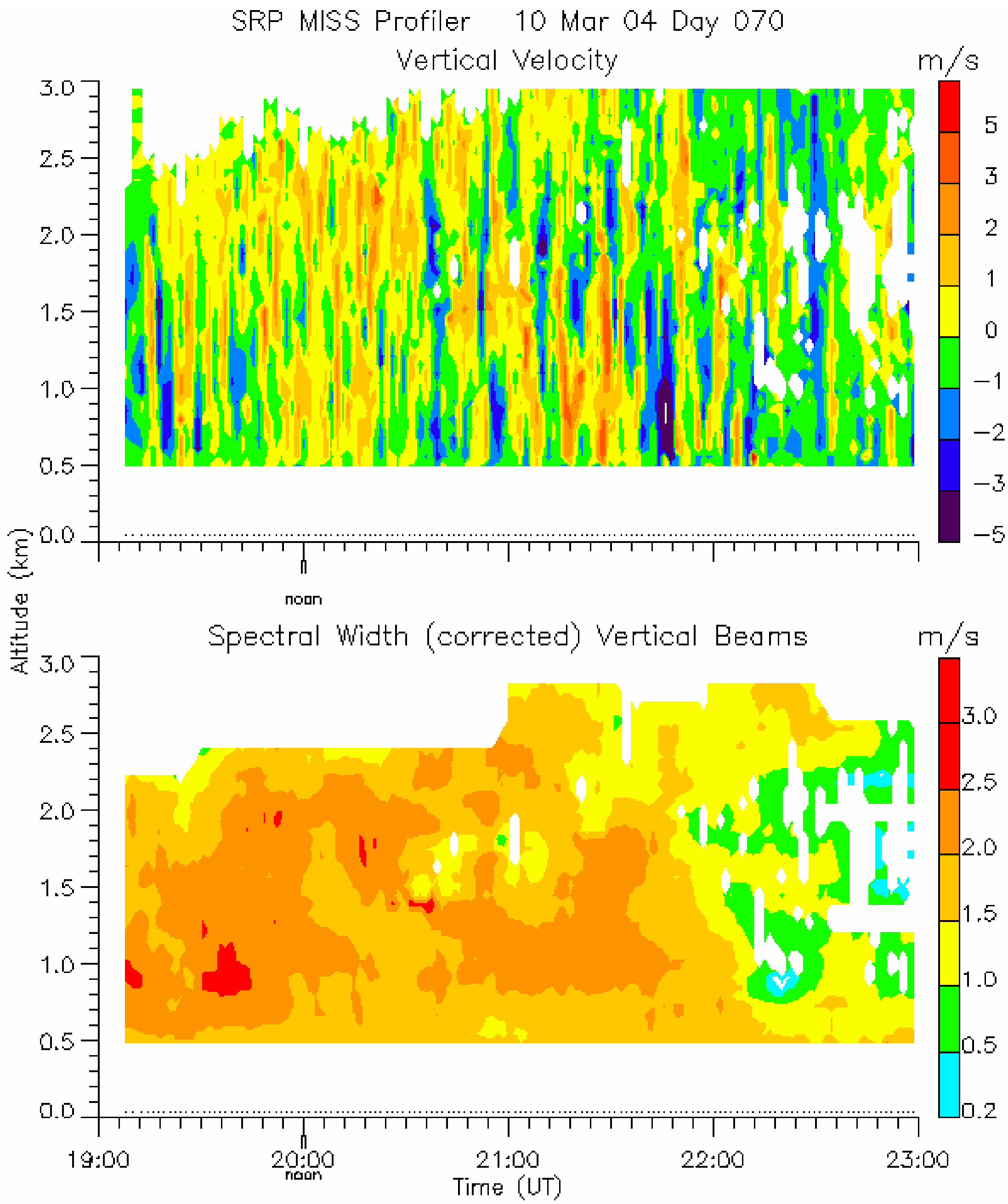

Figure 6: Vertical wind speed (top, negative values downward) and Doppler spectral width (bottom) measured with the MISS vertically pointing beam during the first 4 hours of IOP#2.

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