Action?

Command? read 3

Posted: Sun Jan 24, 1988 2:42 PM EST Msg: HGII-3327-5050
From: J.LUYTEN
To: w.munk

I am using Jim Luyten's telemail system until I get a box of my own again.

First let me thank you for your letters of concern. I am home sdafely again buth
er four weeks I think.
Otherwise am feeling fine, although my long term prospects in the battle againg
something new ad unexpected shows up in a few yearts time. But meanwhile every.

Thinking about heroes of past years, the following question came up and I don't
so ask you: Did Sverdrup get married before or after his magnificent seven yearl
d survive that long a cruise.
Cheers, Hank

Action? answer
Text:
afterwards. gudrun was a beautiful young dental technician in oslo,
and harald met her i believe after his return. she had been
previously married to a dashing young automobile salesman. walter
.

Send? y

Msg posted Jan 25, 1988 1:22 PM EST MSG: KGII-3328-6423

Action?
]
Command? bye

No such command: 'JBYE'

Command? bye

This mail session is now complete.
MAIL DISCONNECTED 00 40 00:00:06:56 96 31

@

STONNEL

Command? read 2

Posted: Mon Jan 25, 1988 5:55 PM EST Msg: DGII-3329-4804
From: J.LUYTEN
To: W.MUNK
Subj: RE: Your Message

thanks walter, seven years did seem a long time for a wife at home

Action?

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Q-060
LA JOLLA, CALIFORNIA 92093

March 24, 1988

Dr. Henry Stommel
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Dear Hank:

After a considerable lapse of time, I am writing to thank you for your eloquent letter about Bert Bolin. It was very much to the point and quite timely.

You will be glad to know that, in part because of your letter, the committee unanimously recommended awarding the Tyler Prize to Bert. Perhaps more interesting, they thought he should get it all by himself, and not share it with another worthy recipient.

Ellen and I received the sad news about Paul Fye's death. One by one the armies fade away. I hope you last for a long time, and I am going to try to do likewise.

With best regards to you and Chickie.

As ever,

Roger Revelle

Posted: Fri Jul 1, 1988 12:40 PM EDT Msg: D011-3613-0952
From: J.LUYTEN
To: w.munk, c.wunsch, p.rhines, w.sturges
Subj: hank

Hank is in the hospital with a broken kneecap, having fallen on the stairs in the Smiith building. He's currently in the FAlmouth Hospital, but expects to be home sometime tomorrow, and back on telemail.
regards, jim.

Posted: Tue Jul 5, 1988 8:24 PM EDT Msg: M011-3017-4080
From: W.MUNK
@To: H.STOMMEL
CC: W.Munk
Subj: Re: Accident

Hank

What a terrible combination of bad luck. I hope you will be up and about in no time.

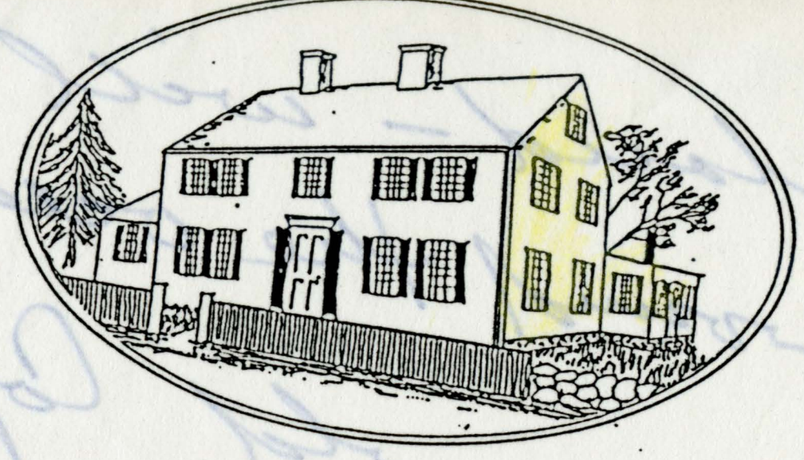
With best wishes, Walter

Posted: Tue Jul 5, 1988 8:33 PM EDT Msg: I011-3617-6053
From: H.STOMMEL
To: W.MUNK
Subj: RE: Re: Accident

dear walter,
Thank you for your kind thoughts. I have the will to get better from this knee injury... it will just take patience and time. (dammit)

I have been reading some of the tidal literature, partly for fun, as I told you earlier. That really is a wonderful paper by you and Cartwright in a
I harmonic methods and
go directly by electrical engineering theory using admittances etc.

With my best wishes to you and Judy.
Hank



SIPPEWISSETT FARM

Henry Stommel
766 Palmer Ave.
Falmouth, Mass. 02540

July 21

Dear Walter,

I happened upon that very nice article in the L. A. Time with your photo and a description of you and your career with prospective of the 70th birthday. It seemed like a very friendly and pleasant article, and reflects great credit upon you — which of course you richly deserve. Anyway — I like reading about old friends,

Your idea about Howard McDonald Islands is delightful. Such a

sound source — so placed — will literally be heard around the ocean — and I don't suppose old Capt. Heard ever expected such audibility.

So, Walter, here are my best wishes and love to you and Judy.

Henry

Dear Walter

When you visit I'd like to ask your advice as to how Webb & I could promote the SLOCUM.

SUN AM
TUE PM

How about some SLOCUMS moving along those two great circle arcs that intersect at Hawaii Is. and illuminate both Bermuda & San Francisco ?

Henry Stommel

Paul Shurcman

Bermuda 453 2835

July 26 '88

SUN AM
~~MON~~
~~SUN LATE~~
~~MON LATE DINNER~~
TUE DINNER

SLOCUM

A SLOCUM is a self-contained steerable buoyant vessel that draws it's power for adjusting ballast from the thermal stratification of the ocean. It reports to a shore-based control center via satellite up to six times a day, so that it can telemeter data, can be located geographically, and can be reprogrammed by the controllers. With a probable horizontal speed of about 15 cm per sec. a SLOCUM could, if skillfully navigated, circumnavigate the world's ocean within five years. It can be steered vertically and horizontally like a small submarine.

A SLOCUM could be used for many scientific purposes. For example: it could map out deep boundary currents or survey the continuity of a feature such as an equatorial undercurrent. It could explore the structure of mid-ocean eddies. It could be steered in such a fashion as to "lock on" to a Mediterranean salt lens, and track it for a prolonged period. It could make long CTD sections: in less than a year it could make a dense CTYD section across the North Atlantic with up to 1800 complete stations. It could be used in a station-keeping mode, so that it maintained a fixed geographical position, thus emulating a weather ship. It could rest for periods on the bottom so as to obtain bottom pressure time series for mid-ocean tide measurements. It could be used in conjunction with tomographic arrays. It could even be used as an economical sea-going auxiliary to augment the oceanographic research fleet. It is possible to

maintain more than 50 SLOCUMS at sea at the same cost as a single research vessel. A fleet of SLOCUMS obtaining deep water data under the umbrella of research satellites might very well be the appropriate instrumentation for matching satellite measurements. HOWEVER, all of this is speculation about the future; what is required over the next couple of years is the design and construction and testing of a few prototype SLOCUMS. It is useful to have an immediate goal for use of the first SLOCUMS: a convincing test of their maneuverability and longevity.

We would like to propose that the SLOCUM be used first in a sense of scientific adventure: a race between three SLOCUMS around the world. There could be three teams: a Navy team, an academic team, and a team of yachtsmen, each responsible for navigating one SLOCUM. Working on a volunteer basis each team would try to bring to bear upon its navigational decisions the best information that it can muster about the details of the deep ocean's currents. How much can the expert skill derived from computer models of the ocean circulation, from knowledge of currents derived from moored instrumentation and Sofar floats, from operational analysis of finding optimum routes, etc. be tested by such a race? It seems likely that by launching such a project we can: wipe away complacency about the present state of knowledge, test modeling ideas, open many questions that otherwise never get asked, learn how to use SLOCUMs to explore features of the circulation and thermal, salinity and velocity structure that are otherwise

difficult to survey. We would also restore a sense of adventure to the public image of oceanography.

Posted: Fri Jul 29, 1988 7:14 PM EDT Msg: GGII-3664-7973
From: H.STOMMEL
To: w.munk
Subj: message for Bernie Zetler

Walter, sorry to bother you with this message, but I don't have Bernie's address, nor a generic IGGP telemail address, so I'm writing Bernie through your box. apologies

Dear Bernie,

Recently Ihave been playing around with tides - in my old age -. I've been analysing some of the many long current meter records obtained over the years by the WHOI buoy group. All in all a wonderful set of data... only partly explored.

Naturally, I quickly made the acquaintance of Paul Schureman's book of 1924,1941, etc. And I began to wonder about him, what he was like, whether I could find a picture, and obituary,etc. I promised Ray Montgomery that I would find out something. Ray himself is pretty sick, and I am trying to keep his spirits up as best I can with various little projects. So I called Steacy Hicks and he told me that you had actually known P.S. a little bit when you started out at the Division.

Can you steer me to anything like dates, education, career, character, personality, etc? There must be something written down somewhere in the literature about somebody who did sucha useful piece of work.

Hank Stommel

Thjank you Walter.

Action?

- .- . .

i had a visit yesterday from richard barber (director) AND
MIKE LEE (THE LEADING ENGINEER) FROM MONTEREY BAY AQUARIUM
RESEARCH INSTITUTE. THIS GAVE ME A CHANCE TO TALK ABOUT
THE INSTRUMENT WE DISCUSSED DURING LUNCHEON AT YOUR HOUSE,
WITH DOUG WEBB.

THEY WERE INTRIGUED. I SUGGEST THAT IF EITHER HANK OR DOUG
GO WEST, THAT THEY VISIT WITH RICHARD AND/OR MIKE.
IT IS NOT IMPOSIBLER THAT SOME EARLY APPLICATION COULD BE
MADE IN MOTEREY BAY. IN ALL EVENTS, BOTH OF YOU WOULD
FIND THE ONGOING DEVELOPMENT AT MONBTEREY FASCINATING.

HANK, JUDY AND I HAD ARRANGED WITH POLLY MONTGOMERY TO VISIT
RAY ON WEDNESDAY 10 MAY, THE DAY WE WENT HOME. POLLY TOOLD
ME ON TUE3SDAY THAQT RAY SAID HE WOULD BE GLAD TO HAVE US COME BYE.
WHEN I CALLED WEDNESDAY TO CONFIRM, POLLY SAID THAT RAY WAS
NOT UP TO IT. I AM SO SORRY I MISSED THIS LAST OPPORTUNITY,
BUT AT LEAST HE DID GET A MESSAGE OF CONCERN FROM US.

WALTER

.

Send? Y

Command? compose
To: h.stommel
CC:
Subject:
Text:
thanks for a lovely luncheon.

richard barger, director of monterey researcvh institute , is comning
for a visit in two weeks. with you permission i would like to ell
him a little about your and doug's ideas.

if you have achance, reming doug that he will send me some general
comments of what kinf of a source one might strive for for the
heard island experiment. requirements are
\ 210 db
50 hz with 25 hz mimum band width.
150 m depthj
reliability, reliability, reliability .....

walter

.
Send? y

Command? read 2

Posted: Thu Aug 11, 1988 9:06 PM EDT Msg: JGII-3685-7598
From: H.STOMMEL
To: W.MUNK
Subj: RE: Your Message

Doug and I would be very pleased if you would be so kind as to tell
Richard Barger about our dreams for SLOCUM.

I'll ask Doug to contact you directly by telemail about the comments
about the Heard Island source.

Regards, Hank

Action?

Msg: JGII-3

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Q-060
LA JOLLA, CALIFORNIA 92093

HERBERT F. YORK, *Director*
Physics

HANNES ALFVÉN
Electrical Engineering &
Computer Sciences

G. ANAGNOSTOPOULOS
Philosophy

JAMES R. ARNOLD
Chemistry

JAMES N. BRUNE
Geophysics

G. ALLEN GREB
History

CLIFFORD GROBSTEIN
Biological Science &
Public Policy

SANFORD A. LAKOFF
Political Science

JOHN M. MENDELOFF
Political Science

STANFORD S. PENNER
Engineering Physics

ROGER REVELLE
Science & Public Policy

HAROLD J. SIMON
Community Medicine

JAMES M. SKELLY
Sociology

August 18, 1988

President's Committee on the
National Medal of Science
National Science Foundation
Washington, D.C. 20550

Gentlemen:

I am delighted to have been asked to write a letter in support of the nomination of Henry Stommel for the National Medal of Science.

The easiest way to describe Henry Stommel is that he is an oceanographer's oceanographer, in love with the sea in all its moods, and with the science of the sea in all its aspects. He is as much interested in making exact measurements from an oceanographic ship in the middle of the Pacific Ocean as he is in developing and applying an elegant theoretical model to interpret these observations. He is as much concerned with oceanographers as human beings and as scientists, as he is in the history of ocean science and of men`s long relationship with the sea.

Stommel is always original, in his thinking, his talking, and his writing. At this same time he is one of the gentlest, simplest, and most charming of men. From his first great paper, in which he showed why the Gulf Stream is so narrow and so fast moving, to his latest published and still unpublished works, he has contributed new ideas and new ways of looking at motions in the ocean which have had a profound influence in advancing the science of the sea. From my point of view, two of the most important of these are his elucidation of the global abyssal ocean circulation, and his recognition of the existence and mechanism of what is now called "double diffusion." He has also helped a great deal in understanding that most mysterious of ocean physical phenomena, the thermocline.

Like many prophets, Henry Stommel has been more acclaimed abroad than in his own country. He is a foreign member not only of the Royal Society, but also of the Soviet Academy of Sciences, the Academy of Sciences of Paris, and the French geographical society. And he has been honored by the Crafoord Prize of the Swedish Royal Academy, the Albert Defant Medal of the German Meteorological Society, and the Grand Prize of Oceanography of Monaco.

As one of the three or four leading physical oceanographers and meteorologists in the world, Henry Stommel should have received the National Medal of Science many years ago. But I feel privileged to recommend that he be awarded it in 1988.

Sincerely,

Roger Revelle

Roger Revelle

cc: James Luyten
Walter Munk

Walter,

Maybe you can pass this

on to Mike Lee of Monterey

Thanks

Command? read 2

Posted: Mon Aug 15, 1988 10:27 AM EDT Msg: MGII-3689-1279
From: D.WEBB
To: W.MUNK
CC: H.STOMMEL

It was a pleasure to lunch with you and Judith at Stommels.
Re sound projector. I sent off a letter to my principal collaborators immediately after returning from lunch. Discussions in progress.

I don't know if we will make much progress, but I will send you some thoughts soon. Your emphasis on reliability (longevity) seems correct.

Re Slocum energy estimate, 100' Kgm instrument, 40 gm axial drive force, 0.2 meters per sec speed equals approx. 0.1 watts continuous,

0.1 WATTS

approx. 10,000 joules per day.

Doug

Action?

Command? read 3

Posted: Mon Aug 15, 1988 10:28 AM EDT Msg: LGII-3689-1292
From: D.WEBB
To: W.MUNK

Walter: May source sit on bottom, or to be buoyed up?

Doug

Action? answer
Text:
i have in mind about 1 meter asbove the bottom, so that morring motion is negligible. walter
.
Send? y

Msg posted Aug 15, 1988 12:53 PM EDT MSG: AGII-3689-5075

Action?

Command? bye

This mail session is now complete.

MAIL DISCONNECTED 00 40 00:00:08:10 66 38

@

```
Command?  compose
To:  H.Stommel
CC:
Subject:  SLOCUM
Text:
Judy and I really enjoyed the SLOCUM MISSION.  How did you deam that up?  I
will forward it to the Packard people on monday.

We had an erxcellent trip to the Greenland Sea, as of this moment all six sourcs
are working, and we did one MOVING SHIP TOMOGRAPHY circumnavigation.  At the
finish we pulled into Longyearbyen inste4ad of
reklavik, quite a change.   Hope you are well, WEalter
'

.
Send?  y

  Msg posted  Oct 16, 1988   3:03 PM EDT    MSG: JGII-3789-4940

Command?  bye

  This mail session is now complete.

MAIL DISCONNECTED 00 40 00:00:11:07 53 52

@
```

Command? read 2

Posted: Sun Oct 16, 1988 7:09 PM EDT Msg: MGII-3789-5237
From: H.STOMMEL
To: W.MUNK
Subj: RE: SLOCUM

i am so glad that your greenland trip was successful. Yesterday I went down to the.WHOI dock to see Carl Wunsch off on the OCEANUS, from which he instrumentation
packages in the SYNOPS region fo the Gulf Stream... also some French instruments.

√ STOMMEL

Thank you for your interest in SLCOUM. And my best to both you and Judy.
Hank

Action?

H. STOMMEL

Bode

THE SLOCUM MISSION

It is difficult to realize that 25 years have passed since I first came to the SLOCUM MISSION CONTROL CENTER on Nonamesset Island in 1996. I was a Post-Doc in Physical Oceanography, and the Navy had just acquired the Island from the descendants of a sea captain prominent in the China trade of the early 19th century. The object of the Navy's aquisition of Nonamesset was to establish a facility capable of monitoring the global ocean, using a fleet of small neutrally buoyant floats called SLOCUMS that draw their power from the temperature stratification of the ocean.

The Navy chose Nonamesset Island for the site of the SLOCUM MISSION CONTROL partly for security reasons because it is isolated from the mainland of Cape Cod, but also because it is close to the Woods Hole Oceanographic Institution and the Marine Biological Laboratory, and a thriving scientific community. It was anticipated that civilian, non-classfied research would be an essential component of the work done.

Nestling low in the hills is the MISSION CONTROL CENTER itself, with its satellite antennas. There are a few houses along the beach facing Buzzards bay for a small permanent staff. Most of the scientific staff commute from their homes in the Upper Cape area, reaching Nonamesset by a small ferry. There is a large dock at the cove, but the one that the ferry uses is at Sheep-pen Harbor on the Hole. There are no automobiles. The buildings are connected by footpaths and there is a narrow gauge railroad for moving supplies from the docks to the facilities.

For the most part the island has been left undisturbed. It is in a pristine state of beauty, tranquil beyond the experience of those who swarm about on the mainland.

The SLOCUM is named after Joshua Slocum, the Yankee skipper who first went around the world singlehanded in a small sailing vessel. There were Slocums on the Elizabeth Islands before, ever since Peleg Slocum of Dartmouth purchased Cuttyhunk, Nashawena and Penikese in 1693. Whether Joshua was related to them, I never have discovered. But my relationship with SLOCUMS has a different genealogy - a scientific and technical one. Perhaps I should begin by saying what SLOCUMS do.

They migrate vertically through the ocean by changing ballast, and can be steered horizontally by gliding on wings at about a 35 degree angle. They generally broach the surface six times a day, at which time they are in contact with the MISSION CONTROL via satellite. During this brief moment at the surface they transmit their accumulated data, and receive instructions of how to steer through the ocean while submerged. Their speed is generally about half a knot. There are military applications for most of them, but about 500 are reserved for purely scientific purposes. They are widely dispersed throughout the ocean. Of the 500 somewhat less than half are assigned to routine ocean monitoring tasks: making soundings of temperature, salinity, oxygen, nutrients, and a host of geochemically important tracers. Slocums were originally designed with a 5 year lifetime in mind, but now many have been in continuous service at sea for more than 10 years.

They had their start because of the growing concern with monitoring the environment: is the ocean heating up? where are the pollutants going? can we construct theoretical models of the ocean circulation that are useful in predicting the direction of climate change? With a necessarily small fleet of research ships, how could numerous widely dispersed measurements throughout all depths of the ocean be obtained on a routine basis?. In 1995 it became evident that much of the oceanographic community had been locked for 15 years into a centralized scientific plan (WOCE) using the outdated technology of the 80's. A really new departure was needed: one that obtained subsurface data on a scale and at a frequency that matched what remote sensing by satellite provided for the sea-surface. Multiplying the number of ships by a factor of 100 was economically out of the question. But the pioneering ocean-engineer Douglas Webb had a different vision of how to garner a harvest of data on a deep-ocean global basis - and this led, after a few vicissitudes, to the Navy's determination to support the SLOCUM MISSION and to the present deployment of Webb's SLOCUMS throughout the world. It has been my career.

So here I am sitting on a lovely October day in the library of MISSION CONTROL overlooking Vineyard Sound. On the grass bank outside the window there is a flock of sheep grazing. I have the daily logbooks of those first deployments and experiments made in the early days of MISSION CONTROL before me on the table. It seems to me that some of the present staff may like to hear about some of the excitement of those early days on a personal level. So that is what I am going to try to do.

As most of you know the backbone of our climate monitoring capability is our permanent fleet of the 160 SENTINEL series of Slocums. There are 42 in the Atlantic Ocean, 38 in the Indian Ocean, and 60 in the Pacific Ocean - at all times, barring mishaps, of course. Each of these Slocums reports in to MISSION CONTROL via satellite about ten times a day and dumps it's CTD soundings (both down and up casts) as well as auxiliary data about tracers from sensors developed by ingenious geochemists in recent years. The navigational data informs us how much the float has been set by the ocean currents it encounters, and the automatic pilots are reset according to a course correction algorithm. Because during the course of the day the casts terminate at different depths, and sometimes dwell for a period at the bottom of the cast, it is possible to recover information about the vertical modal structure of the currents.

Thus we have a basic set of SENTINELS routinely patrolling the ocean between 50S and 50N latitudes, equivalent to a fleet of 160 full-time hydrographic survey ships - making no port stops, using no fuel, and , by international law, exempt from the restrictions on passage through terretorial waters exacted of manned vessels. They are assigned to certain lines: for example in the North Atlantic there are 7 latitude circles being surveyed by 21 SENTINEL Slocums. With horizontal speed of 12 miles a day, seasonal variability of the oceanic gyres can be monitored. Each year we accumulate 150,000 separate CTD casts from the North Atlantic alone.

The prototype of the SENTINEL was launched in 1994, before

the MISSION CONTROL CENTER was built, and the little group of orginators was still working in the attic of the Bigelow building at the Woods Hole Oceanographic Institution. I knew Doug Webb only when he was past retirement age, and he was an active and enthusiastic man. I can only imagine what the sense of excitement must have been in the attic control center when they first started to control the navigation of SENTINEL 1 after it's launch point off Bermuda. According to the logbook it was decided not to confront the Gulf Stream right at the start, so a launch point near to Cape Hatteras was avoided. The plan was to steer the Slocum as nearly eastward along 32N as could be done, making a highly detailed hydrographic section along the way. With some delays, due to a period when communication with the Slocum was interrupted, this section took 198 days. It ended off Ifni on the Northwest African coast, where the RRS DISCOVERY ended her 1957 section long before. She managed to obtain 25 casts. SENTINEL 1 obtained 3820 casts. On this leg the prototype successfully demonstrated that effective hydrographic station work of a routine nature could be done remotely by an unmanned, unfueled instrument package, directed by controllers far away. The atmosphere in the attic must have been ecstatic - rather like that generated in the JPL controllers offices when they successfully rendezvoused Voyager 2 with the moon of Neptune in August 1989. That first SLOCUM devoted to hydrographic work spawned the whole fleet of monitoring SENTINELS that we have over the ocean today.

But SENTINEL 1 had further successes. On a return westward section the following year, it encountered a Mediterranean salt

lens eddy. According to the logbook the presence of the eddy was first detected in the velocity structure. It was decided to go eddy chasing. Soon the high salt at 1200 meters depth became evident. The trajectory of SENTINEL 1 became trapped by the eddy, but after three revolutions it was shaken loose from the eddy. The controllers were now faced with an interesting problem - how to relocate the eddy and implant the instrument package in it again. In those days there was very little information about the nature of the variability of the background current field and small curvatures in the trajectory due to other weak turbulent motions could easily be misinterpreted as indicating where to look for the salt lens eddy. Help was proferred by some numerical modellers in Colorado, who had set up a dynamical model on the basis of the data obtained during the first three revolutions before the eddy was lost. Their model suggested a general amplitude of pulsation and a direction of drift. A random search seemed out of the question because of the limited steered speed available to the Slocum, so inasmuch as the dynamical model predicted a westward drift, and the eddy didn't seem to be embedded in a very strong field of other eddies that was also an intuitively attractive direction to begin the search. If the eddy could not be located, then there was always the option of going back on routine patrol again. As matters turned out the search was successful, and for a further six years the eddy was tracked, measured,and studied as no eddy had ever been before. It was on the basis of this study that the Mediterranean Water Experiment during the years 2003-2013 was designed and conducted, with

spectacular success - revealing a totally unexpected physical process of tracer dispersal, and a rather bizarre mathematical way of parameterizing it in general circulation models.

One of the naive early experiments with Slocums - before the Navy assumed responsibility for them and built the Nonamesset facility, was the International Round The World Race of three Slocums. At the time the whole idea of participating in a race sounded a little disreputable to the rest of the scientific community. But a sense of adventure reinforced by lack of alternate funding drove the SLOCUM advocates to accept the invitation of the New York Yacht Club, and of Australian and French equivalents, to build three SLOCUMS for the purpose. They were controlled from the attic office, but according to instructions received from the three racing committees. The U.S. racing committee had originally suggested that the race be from Bermuda to Bermuda. The final choice was to begin and end at Hawaii; it was suspected to be more difficult to choose good courses north-south in the Pacific than in the the Atlantic, and that would add to the excitement of the venture. It was also agreed that each participant would remain posted about the position of the other two Slocums. Because the Slocums did not have to carry expensive CTD and tracer sensors, they were supplied at less than $100,000 each, and funds of $200,000 a year for the use of the attic control center were guaranteed for five years.

The race was a great popular success. Television programs carried news of the progress of the race on a weekly basis. Lay people became familiar with phenomena such as equatorial

undercurrents, western bounbdary currents, and the Antarctic Circumpolar Current. Mesoscale eddies became a part of everyday language. The National Geographic Society made two television documentaries about the contest. Theoretical pundits offered their advice to all sides. National computer centers confidentially advised their nationals. Cadets at Annapolis tried to organize a last minute entry of their own. The French won with a spectacular score of 708 days.

The significance of this race was that it showed that one could develop skill in programming the SLOCUMS. The imperative of having to decide what heading to choose stimulated modellers and descriptive oceanographers to exercise their minds and computers. As the results of decisions became obvious, from practical application, knowledge grew. And as knowledge grew performance improved. The challenge of the race inspired all the participants into a marvellous exploration of geography, phenomenology, dynamical theory , computer programs and technical development. There is nothing like the need to make decisions to lay bare areas of ignorance that are papered over in textbooks. Suddenly one is faced with the practical problem of finding a western boundary current or riding internal Kelvin waves, or traversing a large unknown oceanic region, learning about it as one goes. Those who were ahead in the race often faced unexpected problems. Those further behind could take advantage of what was thus discovered, and could make use of the new knowledge to pull ahead. Then the same danger of being in the forefront would assail them, and they would fall back in turn. Several remarkable

reversals in fortune of this kind occurred during the race.

In later years, once the SLOCUM MISSION had grown to an effective size, this experience with the navigational tactics of the early U.S.-Australian-French race paid handsome dividends. It evolved into our program of EXPLORER Slocums, today the predominant civilian program of the MISSION CONTROL CENTER. More than 300 Slocums are dedicated to several dozen scientific studies at any one time. There are presently 40 devoted to study of the recirculation regions of both the Gulf Stream and Kuroshio. To date these instruments have collected information for synoptic descriptions and mapping and have gathered statistics about low frequency variability for over 15 years in each region. The result has been a remarkable improvement in the physical understanding and our ability to predict through numerical modelling in both these regions. Other groups of Slocums are devoted to studies of equatorial dynamics, to detailed mapping of the patterns of overflows and western boundary currents in remote oceanic regions, to increasing the precision of local data bases for high quality diagnostic studies, etc. Some of these EXPLORER projects have gone on for a decade or more. One of the earliest was a study of the circulation in the equatorial Indian Ocean, outlined by Dr. John Swallow in a letter to Stommel and Webb in 1988. Several Slocums were launched in the western Pacific off Mindanao. They were steered into various passages in the Indonesian Archipelago, such as the Banda Sea, and then held in position by gliding against the prevailing currents in such a fashion as to monitor the

transport of water from the Pacific into the Indian Ocean through the Archipelago. This part of the project lasted two years, until statisticaly good transport estimates had been obtained, and then the Slocums were used to explore the circulation near the water mass front near 10S latitude in the Indian Ocean, in particular that part of the circulation that passes toward the west, north of Cape Amber, Madagascar. It was found that most of the time this water flows northward across the equator to join the Somali Current. During the later years that these instruments were operating they were used in an effort to discover where intermediate waters escape from the Arabian Sea and manage to move southward across the equator. This particular experiment was followed by many others, one of the more interesting was the survey of the Warren Current, first revealed at about 1700 meters depth in the western equatorial Atlantic Ocean by the time change in the distribution of chlorofluoromethane by Dr. Ray Weiss. The current exhibited a remarkable bifurcation at the equator, some flowing eastward along the equator, some flowing southward along the Brazilian coast as a western boundary current. This bifurcation had not been detected by standard water-mass techniques, and of course became a subject of great interest to dynamicists.

The projects that I have always liked best are the ones that are conceived on the spur of the moment by an inquisitive individual. We try to reserve 20 percent of our Slocums so that we can make them available immediately to pursue such sudden inspirations. They are generally the most exciting; they evolve

in unexpected ways and reveal new dimensions of the unknown about the ocean. We have used small numbers to follow whale migrations. for example, and to decipher the language of whales. We have conducted explorations in regions where political unrest would hamper the conduct of conventional ship operations. And always we have delighted in being of service to scientists with unusual and new ideas that demand examination, even at the expense of the pressures to expand military obligations and more routine civilian monitoring programs. We have found, over the years, that the payoff in increase of knowledge often is greatest the more unconventional the idea, especially when it conflicts with collective wisdom. This policy has not always been easy to justify to our government sponsors, but they have become accustomed to allowing us to utilize a twenty-percent fraction of the observational resources they pay for in these imaginative risky speculative ways. So we have our fun, and they have learned that it pays off.

When I first came to Nonamesset the techniques of graphic displays of data were just emerging from the flat screen of the cathode ray oscilloscope and liquid crystal devices of the late 20th century. Now, of course, the controller is literally surrounded by a three dimensional display that is completely animated. It can be zoomed to any time or space scale. One has the impression of swimming through the ocean , much as being aboard one of those fictional "space ships" that Carl Sagan had in his old popular television programs called "Cosmos". But our control room is a highly versatile submarine. We can observe the data in a vast variety of ways. We can switch from observations

to the predictions of the great numerical models running in other institutions; we can visualize the interplay and balances between various terms in the dynamical equations as computed from data or models, we can scan the history of our subject; we can project ourselves into the scenarios constructed by the paleo-oceanographers; we can project ourselves into the internal structures of matrix relations, invoke a wide variety of functional representations. In short we can immerse ourselves in an infinite variety of ways of looking at the real ocean and our mathematical abstractions of it. This ability is the result of 25 years of accrued observation and skill and understanding. We can call upon the resources of the most informed scientific opinion available, anywhere in the academic world. And we have become so accustomed to facile manipulation of this mass of information that we can scarcely imagine the plodding ways of earlier days.

For those who haven't been in our center before it is worth while to step into the control room to observe the activity. One enters something like an amphitheatre. The lighting is subdued, and the controllers announce that they are about to reprogram the set of EXPLORER Slocums that are involved in a special experiment being conducted in collaboration with scientists at the Institute of Ocean Sciences at Wormley, Surrey, England. This particular reprogramming is being done on a set of six Slocums that carry sonic receivers so that they can locate themselves precisely within an acoustic array laid out along the bottom of the western trough of the equatorial Atlantic. These are specially

instrumented, or hybrid instruments. They are programmed to come to the surface only once very ten days, at which time they transmit to the MISSION CONTROL their accumulation of acoustic reception times, from which we can compute detailed trajectories during their periods of submergence. They are then steered to slightly different locations, where they gather another ten days' precise drift data. During the submergence period they are held close to the bottom so that they will survey bottom currents. The object of the survey is to determine the actual pattern of flow in the region between the equator and 15N where it seems that the northward flowing western boundary current of Antarctic Bottom Water is diverted across the trough to flow, again northward, but this time along the western flank of the mid-Atlantic Ridge - more or less as an eastern boundary current. It is a process than intrigues geophysical fluid dynamicists, and needs to be more firmly verified and described. The project has been going on now for three years. A fair map of the flow pattern along the bottom is emerging.

The voice channel from England comes on. Jake Poldark is on the line. He has a new set of instructions to be relayed to his Slocums. These instructions are made up by Jake's team after study of a data assimilating model of the phenomenon that runs on their TORUS computer. In programs like this they make the decisions. We try to implement them, and if there are troubles that come up, we discuss alternatives with them. But these projects belong to them, and we are just the technical support group.

The Slocums begin to reach the surface and to log into the MISSION CONTROL computer. They all succeed in transmitting their acoustic data, but one is unable to receive its new set of program instructions. For the time being it will operate with default instructions, and if past experience is any indication, the next time it comes to the surface, in ten days, we will be able to make full two-way radio contact. Whatever piece of seaweed or jellyfish draped over the antenna will have washed away. We tell Jake that we'll be in touch next week, and close down the voice channel.

As we see it here at the SLOCUM MISSION CENTER, our job is largely one of technical support. Although the Navy supports most of our activity, it does so by contract with the Joint Oceanographic Institution Corporation. This is governed by a consortium of oceanographic institutions, climate and weather computing facilities, centers for remote sensing, and representatives of the Navy. My staff and I are all employed by JOIC.

Yesterday I was shooting the breeze with a colleague who has a summer house on Cuttyhunk. The view from the windows of his house is spectacular - nearly 270 degrees of horizon - extending from the Bourne Bridge, all along the New Bedford shoreline to Point Judith, and then offshore to Hen and Pigs. There is also a wide view of Vineyard Sound over Canapitset Channel. I guess his view beats what we see from our windows on Nonamesset, although I do think ours is rather grand too. But then I walk into our control room, with its panoply of views of the sea. There are the updated global pictures from the remote sensors on satellites,

there the evolving maps of subsurface variables, there the charts that show the position and status of all our Slocum scientific platforms, and I am satisfied that we are looking at the ocean more intensely and more deeply than anyone anywhere else.

Henry Stommel
766 Palmer Ave.
Falmouth, Mass. 02540

Oct 28, 84

Dear Walter,

Last week I went to Washington to receive the National Medal of Science. I'm pretty sure that you were the one who originally ~~se~~ nominated me —— and I want to thank you for your kindness.

My son Elijah — who is trying to combine medicine & science — came down from the Dartmouth Medical Center as a guest. It was a good occasion to reenforce his motivation to do science. Perhaps it will influence him in a positive fashion. If so, I do have you to thank —— for a happy day in Indian Summer.

Your friend, Henry