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A meeting of the Committee on Geodesy was held September 13-14, 1989. The focus of the Committee was on the applications of geodesy to oceanography, geophysics, space science, surveying, mapping and instrumentation. A report Geodesy in the Year 2000 is under review and will be published during the winter 1989-90. The Committee plans to continue to review the activities and research in geodesy; identify basic research opportunities and applied research needs; and recommend actions to meet future national, societal, scientific and technological demands on geodetic science, including surveying, mapping, and photogrammetry.

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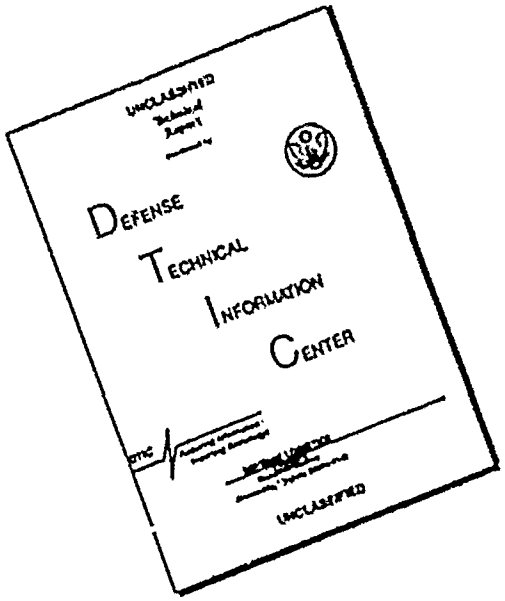

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NATIONAL RESEARCH COUNCIL
Board on Earth Sciences and Resources

Committee on Geodesy

Final Technical Report: Grant No. AFOSR-89-0449

Period of Performance: June 1, 1989 through October 31, 1989

The focus of the Committee on Geodesy is on the applications of geodesy to oceanography, geophysics, space science, surveying, mapping and instrumentation. A report Geodesy in the Year 2000 is under review and will be published during the winter 1989-90.

The Committee met once during the time period covered by the above grant; a report of the September 13-14, 1989 meeting is attached. During this meeting the Committee identified the need for a panel ~~to be~~ set up under the Committee to:

1. evaluate the scientific impact of a global network of fiducial sites;

2. examine strategies for implementing and operating such a network in the light of anticipated scientific return using existing capabilities where possible; and

3. assess whether such a network would provide a suitable global infrastructure for geodetic and other geophysical systems of the next century.

The formation of a Panel on A Global Network of Fiducial Sites will be considered by the Executive Committee of the Governing Board of the National Research Council. If approved, it is anticipated that the panel will have a two year life span and a published report will be issued on the findings. A tentative meeting of the panel is planned for January 24-25, 1990.

The Committee plans to continue to review the activities and research in geodesy; identify basic research opportunitites and applied research needs; and recommend actions to meet future national, societal, scientific and technological demands on geodetic science, including surveying, mapping, and photogrammetry. The Committee encourages interdisciplinary application of geodesy. It expects to take a leading role in relating federal geodetic research programs to the needs of the civilian and scientific communities and to assist these groups by clarifying requirements.

NATIONAL RESEARCH COUNCIL
Board on Earth Sciences and Resources

Committee on Geodesy
Report of the Meeting, September 13-14, 1989

September 13, 1989
Attendees - J. Rundle (Chair), C. Goad, T. Dixon, E. Metzger, J.B. Minster, R. Sailor, H. Orlin, W. Chapman (USGS-Natl. Mapping Div), W. Prescott (USGS/Menlo Park), W. Strange (NGS/NOAA), M. Baltuck (NASA), D. Scull (DoT), D. Alsip (Coast Guard), R. Long (Natl. Res. Council)

Orlin discussed the need for members to be cognizant of any activity that may be construed as bias by a member in the Committee's deliberations and reports.

Rundle noted that 2 members were scheduled to rotate off the committee at the end of the year and that Don Wilbur had declined to serve. Replacements are needed in the areas of instrumentation, geopotential, and classical geodesy/surveying.

ACTION - Rundle to prepare a list of proposed members and alternates, including vitae, in the first two categories and request Ivan Mueller to propose a member and alternate for the third category.

The Committee discussed the activities of Boards and Committees as viewed by the supporting agencies and the scientific community and whether agencies were obtaining good scientific advice from intraagency, interagency and agency organized study groups as contrasted to study groups organized by outside agencies, such as the NRC/NAS study groups. Also discussed was whether the scientific community and federal agencies are better served by committees such as the Committee on Earth Sciences, made up of agency people, or by disciplinary committees such as this one made up of independent scientists.

Committees, such as the NRC Earth Science Committee, are not unusual where there are a number of agencies involved in a common activity. Of concern is that such Committees be politically balanced. Committees such as this Committee can see to it that the activities and programs have an intrinsic merit that transcends specific agency preferences. The NRC Committees do provide the independent view of the community as to scientific viability and procedure.

In the past, this Committee has had difficulty eliciting topics and issues to be studied from the agencies. The Committee might stress those things that it can do for the agencies.

Orlin - (Referring to the tasks of the Committee as noted in the recent proposals for agency support.) The charge to the Committee, when first formed in 1975, dealt. primarily, with the application of geodesy to other sciences, surveying and mapping. Included was also a charge to look to the health of Geodetic Science. Through the years the charge has changed due to the needs of the federal agencies as indicated by requests for specific studies. The original charge has never been formally changed; but, in fact, the charge is exemplified by the tasks enunciated in each year's funding proposal.

Rundle - These proposals characterize the actions of the Committee. The proposal states the long-term goals of the Committee and what it expects to accomplish over the next year or two.

If members or agency representatives feel that changes in the Committee tasks are necessary. they should transmit their thoughts to me or to Orlin.

Orlin - If one examines the tasks, one notes that support for the furtherance of theoretical geodesy has been dropped. This has not been a major activity or desire of any of the federal agencies or from the scientific community. This problem arose at the last spring meeting of the AGU.

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Rundle - As program chairman of the Geodesy Section of the AGU meeting, C. Counselman sent me a letter he had received from Patrick Fell (DMA) in which he lamented the apparent decline of traditional, classical geodesy within the AGU. The AGU program is developed from the papers that are submitted and the few that covered this area were included in the session entitled 'Miscellaneous Geodesy .

Strange - It was unfortunate that the session was scheduled at the same time as the dinner for Ted Flinn. It is doubtful that conventional geodesy will ever return to AGU. It probably would be better to build up conventional geodesy in ACSM (American Congress on Surveying and Mapping). The papers that relate to conventional gravity, such as gravity reference networks and absolute gravity networks, have also disappeared from the AGU program. Those studies don t seem to have a home; they certainly do not belong in ACSM.

Minster - The Committee should express its concern on this matter. There is a tendency to have fewer research papers in classical geodesy, because there are new tools and geodesy is being done in a different manner. This should not translate into conventional techniques not being taught. One does not want to lose an understanding of gravity and the uses for dense measurements on the ground.

Strange - NGS is working with states that want reference networks that approach a part in 10^7. It is inconceivable that those individuals will attend an AGU meeting; they are more likely to attend ACSM meetings. However, gravity should be beefed up in AGU. The AGU is more a scientific society that deals with earth sciences, whereas ACSM deals with more of the surveying and land information aspects. Both organizations are involved in high accuracy geodetic data, but the applications are different. Members of the AGU are interested in the interpretation of the data for earth, ocean and space processes. whereas, members of ACSM are interested in the point values on the ground.

Goad - Those who participate in the AGU sessions are no longer collecting data on a point by point basis. They are interested in data obtained from space platforms to look at wavelengths from 1/2° to 1°. The art of collecting data on a point by point basis is losing importance to those scientists who desire to interpret the data in terms of earth processes and not as bouguer anomalies at a point.

Sailor - Although this Committee is more science than engineering oriented, it is necessary for us to keep abreast of new technology and engineering issues in order to be able to recommend how the latest technology can be applied.

Rundle - If this Committee intends to follow up on the technology issues and the relative role of science, our proposals to the agencies should reflect that direction.

Minster - Strange is correct when he states that researchers are interpreting geodetic measurements in terms of earth processes. The Committee should not be too pessimistic over this development, because this will lead to an improvement in precision and longer time bases over which measurement are made from which we may detect time dependent variations.

Metzger - Researchers would prefer a mass of gravity data, if obtainable from a satellite or an airplane at the same accuracy as one obtains point by point data.

Minster - Geodetic measurements from an airplane is as much geodesy as is taking measurements point by point.

Goad - That is the crux of the problem. The reason there isn't the support today that existed some 20 years ago is that the way in which data can be collected has changed during that period. Twenty years ago everyone collected data in the same way on a point

by point basis effectively using angles, distances and gravity measurements. Today, each agency has gone its own way in an attempt to answer its own questions.

Even this Committee has changed. Members are interested in area wide problems and not point by point problems.

Strange - Obviously the agencies are going about their business in different ways. NGS no longer has any Bilby towers or horizontal control parties in the field. NGS is obtaining high accuracy horizontal positions using GPS, the vertical program is dwindling down faster than it should, and geodetic astronomy is a thing of the past.

Minster - That's what our report indicates. We are on the threshold of a big change in the science.

COOLFONT MEETING

Refer to vuegraphs distributed at the meeting. Where the speakers comments closely followed a vuegraph, they have been left out of this transcript.

Baltuck - The objective of the Coolfont meeting was to develop a research plan for solid earth science in NASA for the 1990's. A plan was necessary as: 1) The NASA geology program, which is predominantly remote sensing with some aspects of the potential field, has been merged with the Geodynamics Branch; 2) The Crustal Dynamics Project is coming to an end in FY91; and 3) There was a perceived need, in the climate of earth system science, where one looks at the earth as a number of interactive systems, to examine solid earth science research throughout the federal government in its interaction with other programs.

The panels were charged with preparing a position paper which would describe the state-of-the-art in their field, the major questions remaining to be solved, and which of those major problems could NASA, with its particular technological capabilities, fruitfully approach. The research recommended by each of the first seven panels (see vuegraph) was examined and coordinated by the Measurement Techniques and Technology Panel, which panel recommended the technology that needed to be developed. The Program Panel examined the input from the science panels and the Measurement Techniques and Technology Panel from which a recommended plan was developed for research in the 1990's.

Position papers were prepared prior to the meeting in July 1989. At the same time the interagency program and international program panels initiated their preliminary contacts.

The Interagency Programs Panel, chaired by Ian McGregor (NSF) and Dave Russ (USGS), was charged with summarizing the types of research undertaken by the different agencies. The intent was to develop a coordination plan which would maximize the use of federal research funds.

(In response to a question) There isn't a formal interagency group to coordinate geodetic activities similar to the one that exists for drilling. However, as a result of the meeting, an understanding was reached on the types of different groups that would have to be put together. One vehicle that has come up since the meeting, which might serve the same purpose, is the CES group. The CES group, at this time, does not have a solid earth science component.

(Comment by Rundle - That is mainly an operational coordinating group and not a scientific advisory group.)

The Board on Earth Sciences is the group that exists for that purpose. There are some questions that came out of the meeting that this Committee should address. One topic that you have been discussing is the mix of space based geodetic techniques that would be best for accomplishing the research goals recommended at the Coolfont meeting and I would encourage the Committee to continue on this effort. However, each agency will have to determine its respective role in these research efforts; nevertheless, the advice of this Committee might be welcomed.

The International Programs Panel, chaired by Chris Reigber and Giovani Sylos-Labini, was charged with developing a plan to coordinate the international program.

Most of the panels had a mix of geologists and members of the geodynamics group.

Program goal - see vuegraph

Scientific Goals - see vuegraph. The goals are not so specific that NASA is impinging on the activities of other agencies. NASA will coordinate with other agencies on all programs that are of interest to those agencies.

(In response to a comment that NASA traditionally has involved in engineering and space technology and these goals seem to define an operational role for NASA.) These goals are for the Office of Space Science and Applications. More and more it is becoming necessary to justify to the entire government hierarchy any mission on the grounds of scientific return.

Volcanology - see two vuegraphs

Land Surfaces - see vuegraph. The interest is in paleoclimatological evidence in the surface of the earth.

Lithospheric Structure and Evolution - see two vuegraphs. This panel considers historical geology, among other topics.

Plate motion and deformation - see vuegraph. This panel recommended global strain observatories (see vuegraph) that would require substantial international and interagency involvement. The need for two hundred Global Strain Observatories was determined on the basis of approximately 1000 km spacing and the amount of land surface. As a number of stations in the CDP project and the Wegener groups can be involved, the number of additional stations will be manageable. The network will address 'earth deformation , constraints on global change', and 'multidisciplinary applications' (see vuegraph). The panel defined the needs for such observatories and the acronym FLINN (Fiducial Laboratories for an International Natural science Network).

Mantle Rheology and Post Glacial Rebound - see vuegraph

The Geopotential Fields panel could be considered from an engineering viewpoint as the measurement of gravity and magnetics and not from a scientific perspective. The panel report fell between science and measurement techniques and technology. The issues to be addressed are presented in the vuegraph (Magnetics and Gravity Field).

Earth Rotation and Reference Frame - see vuegraph

Refer to the Vuegraph titled Effort - Mission - SRT Element, where SRT is NASA s research that is funded out of the ongoing programs. These efforts are to be distinguished from the new shuttle or satellite missions.

MFE/Magnolia is a NASA/CNES mission for high altitude magnetometer. ARISTOTELES is NASA/ESA mission that would start at 200 km for six to eight months with a gravity gradiometer suoplied by ESA. NASA would supply magnetometers and a GPS receiver. During this period it is expected that crustal magnetic anomalies would be observed. After this period the satellite would be lifted to 500 - 800 km which would give us a high altitude magnetometer. Neither of these missions have been officially sanctioned or funded.

g dot is the symbol for the monologist.

Historical Geology comes under Lithosphere Evolution. TOPO=Topographic mission. and SIR-C=Shuttle imaging radar experiment C. The EOS instruments include HIRIS (high resolution imaging spectrometer), which images the land surface in some 228 spectral channels providing a spatial resolution of 30 meters. There is a synthetic aperture radar that uses three wavelengths (L, Z and X bands).

TIR= Thermal Infrared Radiometer, OVO=Orbiting Volcanological Observatory, TOMS=Total Ozone Measurement System.

Major new emphases recommended - see vuegraph. Almost every panel expressed a need for topographic data.

There are a number of areas where there is a need to coordinate activities with other agencies - see vuegraph. SESDIS=Solid Earth Science Data Information System. and PLDS=Pilot Land Data System. There are a number of issues involved in the implementation of the TOGO plan - see last vuegraph.

Minster - FLINN started as a purely geodetic concept. How to cover the entire planet with GPS, a light weight but precise technique? After consultation with other panels, it became obvious that a broader approach was necessary. The Europeans were particularly

interested in a concept that transcended geodesy. The European countries are funded for the deployment of 50 to 100 magnetometer observatories. Absolute gravity measurements at a number of sites are important for providing a tie to space based models.

The question of how this effort would be built on existing structures was considered. It is important to tie this global network very carefully to the existing Very Long Baseline Interferometry (VLBI) network, at a high precision worldwide, in order to have a history and good control on the very long baselines that will be necessary across the Atlantic. Ties to the Satellite Laser Ranging network also will be needed in order to give a good tie to the center of mass.

The Committee needs to discuss the matter of 'precision'. The Coolfont panel determined that the relative position of the sites should be maintained at the 1 centimeter level, when averaged over a 1 day period, and down to a 1 mm level, when averaged over a longer time period. Ties to the center of the earth should be accomplished at the 1 mm level, when averaged over 1 year. Almost all of this can be done, if there existed a sufficient density of geometric sites. (The following statement on gravity data and ties to SLR was not clear.)

If one had a worldwide network, with an intersite spacing of 1000 km covering all major land masses including a number of islands, the use of light-weight techniques, such as GPS or GLRS, becomes much easier. The Reference Frame problem essentially would be solved. We could have extremely dense, frequently occupied, geodetic networks carried out with relatively light weight crews.

The geodesists suggested that when the GLRS is launched a corner reflector would be desirable at each ground site. This would establish the GLRS reference network and tie it to the VLBI and SLR networks. Others thought to generalize the concept of the FLINN sites to include all manner of solid earth and environmental sensors. FLINN, under this concept, becomes a major part of the earth based segment of the Mission to Planet Earth.

Dixon - The rationale for the types of instruments that are to be included at the FLINN stations needs to be carefully considered. Which instruments are to be placed at which stations? Is it necessary to put environmental sensors at each of the 200 stations? This Committee can make a major contribution by recommending a mechanism that can be used to make these decisions. In addition, we might consider how to involve individuals and agencies, both national and international, that have the expertise to devise a reasonable program.

Minster - It would not be wise to have all instruments at all locations. Some of the sites may be related to areas. VLBI sites will not be established everywhere; only about 12 VLBI stations will be needed. Magnetometers might be set at 50 sites. SO_2 measuring sensors would be set at active volcanoes.

Dixon - SO_2 sensors might, in fact be placed away from active volcanoes in order to obtain a base level calibration for volcano monitoring.

Baltuck - The tentative suite of instruments will probably be recommended by the geophysical community. That list could be modified as other needs were identified. Next would be the requirements of other solid earth science groups, followed by the other disciplines; an attempt would be made to incorporate these other sciences without compromising solid earth research. We visualize the program as a multistep, iterative process.

From a NASA perspective, the tracking program supports two other NASA programs: TOPEX and (not mentioned). Therefore, the SLR stations would have to accommodate that program as well as solid earth research.

The program panel is investigating the cost at this time. The cost will depend upon the degree of coordination with other agencies and other countries. There are estimates that range from zero base growth to 20% growth. An augmentation of several millions of dollars each year will be necessary.

Minster - Referred to the Executive Summary of the Coolfont report distributed at the meeting (7 pages).

Strange - Much of the program is in place. For example, the VLBI sites in Tasmania, South Africa, Brazil, Antarctica (2 sites), and Tahiti will be in operation during the early stages of the program. With the northern stations presently operating, there aren't many more fixed VLBI stations that need to be established. One should not underestimate the number of permanent GPS stations that are close to being operational; there will probably be many more than 200. NGS is presently obtaining data from 14 tracking stations from which NGS will be computing and distributing orbits.

Programs on the monitoring of isostatic rebound are under development. An agreement with the Canadians is about to be signed. GPS stations are being established for navigational purposes; that will result in a permanent network of stations along the coast of the US which will provide GPS data for navigation and for monitoring isostatic rebound. Many small island nations have hopes of establishing GPS stations. It may be that the cost of the effort may be overestimated, especially for GPS and VLBI.

The number of fixed and mobile absolute gravity meters need to be determined. NGS s is used in the mobile mode.

The biggest problem may be that of handling the data; sorting them out and getting them out to investigators and other users.

The actual expenditure for instruments will be smaller than anticipated. Most scientists and engineers, even among the surveying community, are going to the dual-frequency instruments which have come down to about $30,000 and should be in the $20,000 or less range in the next decade.

The solid earth community needs to be specific as to where these instruments will be needed. The community should not be constrained by budgets, but should devise a plan that incorporates what is really needed. With programs rising everywhere, plan that indicates the types of observations needed and the sites that would be most beneficial would encourage others to adapt their programs and to join the FLINN effort.

In October NGS will establish a regional network of close to 100 stations at a part to 10° across Oregon. Although this network is not being done for geophysical purposes, it would be helpful to know what a larger community would like to see in terms of a monitoring network. This Committee and other groups should design programs on a region by region basis as to what type of monitoring or measurements would be beneficial for a region.

Once a dual-frequency GPS system is in place, only the continuing need to track the location of the measurement point would prevent one from obtaining information on long term deformation.

Dixon - That's not entirely the case. If one is not careful in placing the antenna, one could be plagued with multipath.

(In response to a statement that excellent results would be obtained over an average of observations over a year.) Scientists prefer not to average over a year; motions over a period of weeks or days or hours is what is desired.

Baltuci - What may be needed is an assessment of where stations presently exist and where stations are being considered for the future.

Strange - What is of concern is that the geophysical community may define their requirements so stringently that the mass of data that is being collected will be ignored and then decide to obtain new sets of data.

Minster - What is needed is an infrastructure that will allow groups to contribute to the program. What will be difficult is to commit geodesy to a one day time scale worldwide which implies telemetry for all the data, as for some applications real time analysis is required.

Goad, Strange - Not everyone will require real time answers. Plate motion is not needed real time.

Rundle - If the FLINN network is to be a fiducial network, standards need to be developed. Not all stations can be part of the FLINN network. If Strange is correct and many stations are to be in operation, one may have to be selective in which stations are chosen as FLINN stations.

Strange - The problem may be that the program becomes exclusive; this may be used as a justification for building a network outside of the existing stations. That would be a waste of federal funds. This may result from a standard that says that unless millimeter accuracy is achieved the data are not of use to solid earth science. It is not true that millimeter accuracy is necessary in order to obtain useful geophysical information.

Prescott - It would be important to know whether millimeter accuracy is being achieved at these stations. There may be some value to stations that are not superprecise; but, there are some things that can be done if one knows that a station is stable and its position is determined at the millimeter level. Possibly not all stations need to be at this superprecise level, but there clearly is some value to having as many stations as one can afford at a superprecise level. The only way that level can be maintained is to have standards that stipulate such things as: how the marks are established, how well the stations are tied to the surrounding area, and the monitoring of instrumental changes when antennas are moved. Some of the cost of the program will be borne by those who obtain GPS data for other purposes and some of that data may be of use to the program. However, just because a group obtains GPS data and transmits them to a central location doesn't necessarily mean that the data will meet some of the goals of the FLINN network.

General Discussion - The Fort Davis station was discussed. Although NGS will be removing its equipment, the antenna will be left in place. Therefore, the position can be monitored by anyone bringing a receiver to the station. The need to measure the position every five days was contested with no meeting of the minds.

Rundle - Problems arising from data formats and data types contributed to the FLINN network and the instruments used need to be resolved.

Goad - The efforts, missions, and SRT elements vuegraph does not indicate the 12 VLBI stations under missions.

Baltuck - SRT element is ground based activities; the on-going part of the program. Missions are space missions that require launch. VLBI does not require a launch and does not require a new line item in the budget.

Goad - Based on this vuegraph it appears that the mission funding is protected. The FLINN network appears to be unprotected. How can we be assured that a continuing observing campaign is protected? Neither VLBI nor GPS is highlighted. Are these efforts protected?

Baltuck - One reason that FLINN has been embraced is that it makes sense scientifically, and is a good use of resources. If NASA can coordinate the agency and international activities. It also stands out as a separate defined issue and is close as one can come to a new start mission in an ongoing program.

Goad - Why can't FLINN have mission status? Certainly, a plan contributing to a long term geodesy/geophysical observing campaign that is on a year to year funding cycle, or at most a three year funding cycle, will not have the same status as long term mission, such as the mission to Mars. There should be a more overt support for those programs that do not necessarily have their origin with NASA such as the GPS program that originated with DMA.

Baltuck - The CDP somehow got project status and an effort can be made to achieve the same for FLINN. AS there isn't a specific flight associated with FLINN, it may be difficult.

(In response to a suggestion that FLINN be associated with a satellite mission and a question as to how funding for EOS is guaranteed as that program has ground and airborne sites.) The support for the prototype aircraft sensors comes out of the ongoing SRT program: because it is EOS associated, the funding is sometimes at the expense of PI support. That support is entirely at the discretion the program managers working with the EOS office. Neither VLBI nor GPS is protected under NASA missions.

Strange - Most of the fixed VLBI stations are protected because they are part of the Earth Rotation Service.

GPS Coordinating Committee

Dave Scull (DoT) - (See 17 vuegraphs distributed at the meeting)
(DOT/RSPA, Rm 9402, 400 7th St. SW Wash.DC 20590, 202-366-4355)

History of Civil GPS Service - The USAF Joint Program Office decided in 1985 to set up a reporting system for both military and civilian users of GPS. The University of Texas (UTARL) was given a contract to look into a civil OPSCAP (Operational Capability) system.

The Civil GPS Steering Committee endeavored to define funding sources. Funding through private sources, without government support, was considered; whereby GPS would be sold through the private sector. However, most felt that the government should have responsibility, primarily from the liability issue. However, under investigation are means to make the service self-supporting by selling GPS related material to the public.

FAA was not interested in the GPS service as their traditional notice to aviators seemed to suit their needs. The Coast Guard was interested, because of their operation of navigational systems such as LORAN, etc. for the civil community, and in 1989 was designated the civil interface for a civil GPS service.

The Steering Committee grew over the years including individuals from government agencies, and the scientific and the private sectors. In 1989 was divided into two parts: An executive committee, chaired by Scull, composed of only government agencies (including individuals from NATO countries); and a general committee that is open to the public, chaired by the Coast Guard.

Klepczynski (US Nav. Obs.) and Allan (Natl. Inst. of Standards and Technology) are working with DoD on the problem of selective availability. They have proposed that GPS signals be transmitted in the clear from at least two satellites so that time transfers can be accomplished. This proposal has been under review by DoD since April.

Norway has a large GPS differential network. The Royal Institute of Navigation (U.K.), another civil interface, is interested in establishing nodes in Europe for obtaining GPS information.

Networks are being established by NGS and international organizations. The Coast Guard is looking into a differential network to support their programs such as buoy tending. The Canadians are considering an active control network and state highway departments are setting up network. At some point there needs to be coordination between the many participants, otherwise many stations may be redundant.

The main thrust of the committee is to solidify requirements for the surveying community, the timing community and others.

UNAVCO has attended a previous meeting, but may not attend the September member. At various times JPL (Ruth Nielan) and NASA (HQ. and tracking program) have participated. NASA has no representative on the standing committees, although Hal Theiss said he would be a member of the steering committee, but has never attended meetings. The Bur. of Land Management, Forestry Service, USGS, and NOAA participate in the sessions. Receiver manufacturers have participated (Trimble, Magnavox).

Lt Cmdr. Doug Alsip - See 5 vuegraphs.
(Commandant (G-NRN), US Coast Guard, 2100 SW 2nd St. Wash.DC,202-267-0287)
Alsip is project manager for the Civil GPS Information Center.

The Civil GPS Service consists of three elements: (1) PPS (Precise Positioning Service) which requires cartography and access to the high accuracy positioning service; (2) The Information Center; and (3) The Precise Ephemeris Service.

The information center will provide publications that describe GPS, the services available, and the types of information that is available, including how to obtain the information and how to use it. The publications will be available from NTIS.

The Center will adapt the DoD interface control document 200, the interface between the space segment and the user segment, to provide a civil oriented engineering reference. The reference will have information on how to build a receiver, the specifications, and the navigation message.

Initially, the real time information will include the current status of the constellation. Future changes in the constellation, such as anticipated eclipse or maneuver of the satellite, may be available up to six months in advance. The almanac is a set of lower precision ephemerides that can be used to make satellite coverage predictions; mainly used for planning purposes. The system will be implemented later on this year or early next year.

Information may be available on the ARPA net; but, it is not contemplated at this time.

Broadcast ephemerides information will be provided in a time frame that is under negotiation with DoD. At the present time the data must be protected for two weeks; but, there is a possibility that that time frame will be shortened. Within reason anything that is unclassified can be made available.

The program is being designed so that charges can be made for all the services. However, it is not anticipated that there will be charges, as the cost of implementing a system of charges would be time consuming and expensive. In addition, it would cost about 40% more to operate the system.

The program manager office will attempt to answer any questions on GPS.

Goad - How will the replacement for the ICD 200 differ from the original?

Alsip - It will explain things in greater detail. The replacement should be more like a technical reference. It also will have references to the literature. Funding permitted, it should be available within a year.

The archiving requirements are under study. Records will be kept of all information that is sent out.

For the present the only ephemeris data that will be available will come from NGS. However, in the future, information from the international community may be available.

The data base will have the capability to accept data from third parties. However, the initial implementation will have no outside input. We would have to look carefully as to how third party data would be handled. If an information exchange form is designed, the data will be maintained separately.

Current information and news items will be disseminated [illegible]gh a news letter and the electronic bulletin board.

Rundle - The Committee encourages the development of the Coast Guard information center. It is a program we have tried to encourage over the past few years.

Strange - With respect to the civil GPS Service refer to a two page letter dated September 12, 1989 signed by Strange and addressed to 'Dear Colleague' distributed at the meeting. As chairman of the subcommittee on Surveying and Precise Positioning, Strange has requested those communities to provide him with what they would like from a GPS service. The request has been distributed to those in the academic, scientific, surveying and engineering communities.

NGS obtains from DMA the precise ephemeris (originally prepared by NSWC) that is prepared by the DMAHC (DMA Hydrographic Center). These orbits are obtained on about a two month delay basis. They are distributed to anyone in the US; to anyone outside the US, a case by case approval from DMA is required.

NGS attempted to produce orbits about one year ago, but the accuracy of the orbits was not adequate. Recently, the NGS orbits have been comparable to the DMA orbits. It is

planned, by the end of November, to begin the distribution of NGS orbits; there are no restrictions on the distribution of the NGS orbits. NGS can also distribute the tracking data from 13 tracking stations (8 CIGNET stations and 5 DMA stations mostly in the southern hemisphere). The CIGNET data can be distributed freely; however, the data from the DMA stations would have to be cleared on a case by case basis with DMA. This not a security problem, but outside the federal government DMA needs the approval of the host country. NGS expects that within one year there will be a sufficient number of tracking stations and we will no longer be dependent on the DMA stations. DMA has recently shown increased interest in becoming involved with the tracking and other activities of the civilian community.

NGS is finalizing the format in which the orbits will be distributed. The format that is chosen will affect the software produced by manufacturers that is distributed to users of their equipment. Once the format is finalized, it will be difficult to change it to any major degree.

GPS Orbits - Geodesy/Geophysics

Prescott - (Recently appointed Branch Chief for Tectonophysics at Menlo Park/USGS) See 31 Vuegraphs distributed at meeting.

GPS, for many users, is not operational as a tool. GPS is still in the development stage, although one would not get that impression from the literature. In order to use GPS for geophysical purposed, a great deal of effort is required today. GPS needs to be adapted to use by geophysicists who are interested in the earth as contrasted to those who are interested in orbits, in finding better algorithms for resolving biases, in building better instruments, and in developing static techniques.

High precision GPS is needed, as displacements are small, in order to obtain results over a four or five year period. (See vuegraph). Rates along the San Andreas Fault are of the order of 20 mm/yr. With one cm GPS motion along the entire area can be seen in a few years; but, if one wanted to determine how that movement is distributed, one would need GPS or another system that would be precise below a centimeter. High precision can be obtained from GPS, but it requires a monumental effort (see vuegraphs of San Francisco Bay, Central and Southern SF Bay, California Sites, GPS & VLBI comparisons, and Loma Prieta).

An experiment done in Iceland, where everything was not ideal, is discussed in Surveying and Mapping (see vuegraph). Iceland is not ideally suited for satellite coverage which resulted in less than 4 to 6 hours of tracking each day. In general results from 1 to 5 parts in 10^6 were obtained. This experiments further indicates that without care it is not trivial to obtain high precision results.

Requirements for precise results (see vuegraph) - Preprocessing is essential to resolve such items as clock problems, clock offsets, and different types of receivers. In order to obtain high precision, particularly on long lines, the positions of the satellites are essential; either orbits of high precision or a fiducial network are required.

(See 5 plots) Problems faced using GPS data - First plot is of double differenced raw phase data, after subtracting the orbit, for satellites 11 and 9 at stations Allison and Yellowknife; data is taken from two receivers looking at two different satellites and are difference twice. The scale is in units of 10^7; the difference of about 30 million cycles mostly occurs at discreet jumps. The next plot is of the same data after they have been cleaned up; the jump is still visible but the difference is about 90 to 100 cycles. Next is a plot after the data have been cleaned up: now one sees structure that comes from something else because the cycle slips have been removed. The data are ionosphere free data. One needs to be certain that there are no jumps in the data.

One of the reasons that GPS is so difficult to use today is that all the data required a great deal of preprocessing. In addition, for each campaign there appears to be a separate set of problems that need to be analyzed by an individual well versed in GPS.

Orbits are what make GPS difficult to use. A one meter orbit error produces about 5×10^{8} error in baseline length or relative position. In order to obtain data at 1×10^{7} level orbits need to be known at the 1 meter level; although it would be nice if that error can be eliminated entirely by reducing the error to 20 cm or less. There are two

methods for treating the problem. One is to obtain orbits from an external source, such as a the broadcast orbits, or the precise orbits produced by the NSWC, or the orbits distributed by NGS. One can also obtain fiducial data from tracking stations and model the orbits as part of a solution.

Most investigators interested in precise data use the fiducial data. Most of the orbits being distributed aren't calculated using double differenced phase data; most are calculated from pseudo range data, because of the work involved in cleaning up the phase data.

The problems discussed have been solved at the research level. But, we are not yet at the level where an investigator can use the orbits without a great deal of effort. There is no source for orbits at the submeter level on a routine basis. Most investigators, nevertheless, would opt for using the fiducial data and estimate the orbit as part of the solution in order to obtain the highest precision.

Fiducial data cause some problems. The fiducial data takes up a good percentage of the time used to process the data. For small campaigns, where the broadcast orbits can be used, the data can be processed in the field, keeping up with 4 or 5 receivers. But, when one deals with fiducial data, that is not possible.

One of the bigger unsolved problems is that the location of the fiducial receivers isn't under the control of the user. If the reference frame rotates, one does not know whether the changes seen are due to the reference frame or to local variations in the earth. The fiducial network being used is run by CIGNET. The problem with these data is that they have not been as reliable as users would like; there have been changes in the antennas and receivers which have not been documented and there have been many days when receivers were not in operation at a number of stations.

All of the fiducial sites are tied to VLBI stations; however, the ties have not been done in a methodical way and not been documented. Some of the fiducial sites are tied to local surveys.

Dixon - The ties are not usually between two marks, but between a theoretical phase center of a very large radio astronomy antenna and a mark that may be a distance of 1 or more kilometers. Getting the phase center of the antenna is the real problem.

Goad - If that is the case, how can repeatability between VLBI baselines be tested over a ten year period ? The observations are done at a mark, not a phase center.

Dixon - That is true for the mobile VLBI sites, but not for the fixed sites. All of the fiducial sites are fixed.

Goad - The physical phase center of a VLBI antenna changes with time. Therefore, the only way in which baselines can be compared over a ten year period, or over a day, is to model that physically changing electronic center to a position in space.

Dixon - If one always looks at the same radio sources, doesn't that lead to a constant error source?

(In response to a question) Repeating the tie will improve the situation.

Prescott - Both the local survey and the tie to the VLBI site may be in error. Also, the receivers and the antennas have changed due to evolving GPS equipment and the concerns over multipaths. Changing receivers raises the problem of how the data are to be mixed: such errors are at the centimeter level and may not be troublesome at the fiducial sites. The fiducial stations are moving, as are all points on the earth' surface; hence, we need to update the coordinate system. A coordinate system that is time tagged is required.

There are a number of coordinate systems (MIT, Univ. of Texas, JPL). The problem with using someone elses coordinate system is that everything is changing (stations, antennas) and, in order to use GPS one needs someone who specializes in knowing the coordinates of fiducial sites.

Strange - Frequently, the interpretation of the geodetic survey by a non-geodesist that has been in error.

Prescott - The solution is the attainment of orbits from continuous data, from a large set of stations, that are reliable and clean. This would allow investigators to calculate their own orbits.

At present we have available clean tracking data, occasionally from a minimal set of stations, with fuzzy location history. This may sound negative with regard to the CIGNET network; but, that is not the point. CIGNET has been a major breakthrough, in what this network has allowed us to accomplish with GPS. What we need to do is focus on means for making the network more useful.

We need clean data, the positions of the antennas (although the coordinate requirements are not clear), a record of the locations of all antennas through all moves and replacements, and a sufficient number of stations to insure fiducial coverage globally.

When hardware is changed we need a long overlap between old and new hardware. Probably, the best practice is to put out new hardware gradually; new receivers should be placed at one site and tested thoroughly before implementing all sites. Then the long lag time in processing GPS data, a month or two is insufficient time to fully evaluate the effect the changing of antennas or receivers will have on users of the data.

Dixon - I agree with what Prescott has presented with the exception of the need for ties. A study of the CASA UNO data set involved the comparison of a number of fiducial networks which include a number of long baselines. Many of the baselines are 500 to 1000 or 1200 km in length. Those baseline estimates are very sensitive to orbits and, hence, very sensitive to the available fiducial networks. A comparison was made of US only, US/Europe, US/Australia, and US/Europe Australia networks and the entire network that includes Kokee, Hawaii and American Samoa.

The only true fiducial stations are the three US stations. These stations provide VLBI data, approximately at the centimeter level. Although there are VLBI sites near all the European and Australian stations, ties were not available, or were thought not to be adequate, at the time the study was accomplished. Therefore, those stations were not fixed in the analysis, but were estimated; although very tight a priori constraints (several meters) were applied.

It is surprising that even though one does not know the locations of the tracking sites down to the centimeter level, they contribute significantly to improving the orbits. This is evident from the graphs where a least square fit to the east and north components for the US/US, US/Europe and US/Europe/Australia data were obtained. The baseline precision is expressed as $(a^2 + b^2l^2)^{1/2}$, where l = baseline length, and a and b are coefficients; a is a function of instrument noise and b is a measure of the length dependence. One should note that the b values, as stations are added to the tracking network, improve from levels of 4 to 6 parts in 10 to the 8th down to levels around 2 to 3 parts in 10 to the 8th; even though the European and Australian stations are not treated as VLBI fiducial sites. It appears that, if the geometry is good, one can accommodate for poor ties.

When Koki and Samoa are added to the network, the data set is not improved. Although it is not clear why this is the case, it appears that the data noise at those two sites during this experiment was too large.

Rundle - At our last meeting Strange suggested that the NGS would operate a global tracking network.

Strange - The present operating stations have moved to the point where there are now mini macs at Westford, Richmond, and Mojave. Others have mini macs and NGS is in the process of procuring one which will be installed at Koki and Hawaii. NGS is obtaining data from DoD stations which includes three in the southern hemisphere: Smithfield, Australia; Quito, South America; and Bahrain, Persian Gulf. NGS is getting 30 second phases for those stations which are used for orbit determination.

In October 1989 NGS will work with the University of Tasmania and with a group in South Africa. Those are fixed VLBI stations. Before the end of the year it is hoped to have receivers at those stations.

The Norwegians have purchased a number of ROV receivers which have not yet been delivered. NGS will examine the data from those systems. It is possible that there will be GPS stations in Antarctica and Tahiti, if fixed VLBI sites are installed at those places.

The documentation for stations was poor in the past, as these stations were used as orbit determination stations and not fiducial stations. Clearly, the location of stations and the position of antennas are items that must be addressed.

One problem is the computation of very high accuracy orbits. For that a small number of stations (of the order of 12) are needed around the world. Another problem is the establishment of local fiducial networks which require some redundancy. It is hoped that there will be a large number of stations in the US to provide this redundancy. A receiver should be placed in the state of Washington in order to strengthen that VLBI station.

The mini macs do not produce much in the way of cycle slips. Therefore, double differencing is feasible. Shortly, Japan, Koki, Mojave, Richmond, Westford and Betsel will have mini macs.

Rundle - What is needed, by whoever maintains a network, is a strong commitment to producing high quality data from the fiducial stations.

Strange - The point is that NGS cannot accomplish its global mean sea level program without those stations. Once the fixed VLBI stations are in operation in the southern hemisphere, we need to look at the laser stations to determine whether to send mobile VLBI to those stations.

NGS does not plan to remove the antenna at Vandenberg. But, NASA needs to provide equipment to be used at the site. The collocation with a GPS receiver has been going on since mid-1986.

Minster - We need some standards or rules that everyone can agree to, when equipment is changed at a site. One of Prescott's viegraphs indicated that there is no bias between the GPS and VLBI determinations at Vandenberg and Mojave. Yet a straight line fit of the data points indicate different slopes for the GPS and VLBI data. Therefore, the criteria one should adopt is that equipment should not be moved until the slopes are in agreement.

Strange - There is nothing in the works to prevent that from happening, except that the necessary equipment must be found. One could install the TVDS's. One could also put more equipment in the antenna trailer. As the antenna will not be moved, there will be no loss in continuity of VLBI measurements.

Rundle - How can the user community register their concerns about these orbit questions?

Strange - NGS should be contacted. NGS will not be in a position to monitor the vertical position of stations worldwide to a few millimeters, if NGS does not maintain a coordinate system. Originally, NGS established the fiducial stations out of its base program. But, now with the Global Climate Change program NGS has specific funding for accomplishing the worldwide observations It wouldn't hurt for the user community to point out how important these stations are.

Rundle - Possibly the Committee should take a stand on this matter and make some strong recommendation on the funding of enhanced fiducial network.

Strange - Is it possible that the data from the ROGUE receivers at the Deep Space Net sites can be made available to NGS for orbit determination?

Dixon - It is the subject of intense negotiation between two branches of JPL: The Geodynamics and the Deep Space groups. Three months ago that agreement was not in place; but, I assume that will be worked out.

Prescott - USGS has in the past tried to influence NGS; but, they have not been very responsive. However, with a fixed budget, an agency cannot be responsive to the needs of every agency. I haven't found NGS, as the operators of this system, to be responsive to the comments of users. Since my March 8, 1989 memorandum to Max Ethridge that dealt with GPS fiducial sites in North America, to which a response has not been received, an international oversight committee has been setup under IUGG to keep track of CIGNET. Jerry Mather and Ruth Nielen are co-chairpersons and Prescott may be the only other US representative.

Rundle - Recommendation 2 of our report could be revised to include fiducial stations.

Strange - Wouldn't it be best to have as many of the GPS orbit stations as possible operating at VLBI sites, so that any differential station motion doesn't have to be solved for at the same time that one computes the orbit? At a meeting in Edinburgh, Ruth Nielen stated that there wasn't any point in having more than one GPS station at a VLBI site. If stations are not collocated, one needs to compute the motion of the station at the same time that the orbit is computed. If VLBI monitors the station position, one would be better off than if one had to solve for the position.

Dixon - One should have at least three such stations in order to define a reference frame. It is doubtful that all VLBI sites need GPS observations. In the first six hours of observations, so much data are collected and the data strength of GPS is so great that one can compute the station location adequately enough for orbit determination.

Strange - That is the crux of the problem. If one is considering decade-long monitoring at the millimeter level for polar motion and earth rotation, one must have VLBI to monitor the differential plate motion.

Dixon - One needs a subset of the VLBI sites at which GPS observations should be made. What is in question is the size of this subset. One reason for not including all VLBI sites is that fixed VLBI antenna sites can have very bad multipath and sky visibility characteristics. At many of these stations, it would be best to get away from such an environment and observe in the open where there is good sky coverage and one need not worry about multipath or obstructions.

Goad - One could observe at an offset of 800 meters and still satisfy Strange's comment.

Minster - At the Coolfont meeting, it was determined that about 12 VLBI sites would be needed to define the reference frame. This number is not fixed; it represents an order of magnitude determination of the number of sites that should be implemented by a complete suite of instruments.

Strange - The stations that should be tied in are those that contribute to polar motion and earth rotation because those stations will be observing every five to seven days. The accuracy of the differential positions from these sites will be very good which will permit millimeter level accuracy. Those are the sites at which NGS plans to establish GPS stations. One also needs to maintain the laser measurements in the system.

Minster - If there is a requirement on the observer to obtain data at some precision, one needs to inform the observer on the amount of averaging that will be permitted. If a millimeter precision is required over one hour, it may not be possible. But, if averaging of a dense set of experiments over three months is permissible, there may be some hope. The goal established at Coolfont is the attainment of one centimeter precision over twenty-four hours.

(In response to a question from Metzger) The variation is gravity at a site, in a recent experiment, was compatible with the free-air gradient and the satellite laser ranging measurement changes in height; except that the coefficient had the wrong sign. The magnitude was a few microgals (exact number not clear on tape).

Prescott - Interesting data have been obtained in southern California correlating changes in differential gravity with changes in elevation and strength over a period of a few years.

General discussion followed on absolute and differential gravity measurements and environmental influences, such as water table and barometric pressure, that have to be considered before repeat measurements can be compared. Considerable effort is needed in maintaining stability, repeatability and accuracy of gravity measurements.

A number of groups are working on G fifth-force class of problems. In most of these experiments the variations are within the error bars. Eckhardt is the only one that has a signal outside his error bars.

Future Committee Activities

Orlin - Our budget requests for 1989-1990 include support for three meetings of the Committee and two meetings of a panel. Responses will probably not be received before October 1, 1989. Thus far we have not received any denials.

As this is the last meeting of the Committee this calendar year, the Committee should plan on the continuation of the Committee and the formation of a panel. If sufficient funding is not received, we cannot perform the tasks. The funding situation should not influence our thoughts on our program at this time. In fact, if the panel study is of great interest it may ease the funding situation.

Rundle - At the last meeting a number of critical problems were discussed; the funding and attention to orbit determinations was one of them. There is also the problem I proposed in the letter to Brian Skinner. I proposed that we consider a follow-up to our current report which might be entitled "Geodesy in the 21st Century: Priorities in a National Program". The aim would be to examine, in detail, the issues noted in the executive summary.

Over the past 100 years NGS was the major agency responsible for maintaining first-order networks in this country. This activity is now being done by a multiplicity of agencies; including technology development and observing. In this environment, how can we assure that a coordinated and continuing program will be established for the next century?

Orlin - The Committee would need to develop a project plan to accomplish this study. How would this coordination operate in the federal government, particularly when the geodetic measurements that are our concern are in diverse agencies with their own budgets and priorities? In the 19th century and the early part of this century, NGS was the focal point for all geodetic data. However, today, precise geodetic data are being obtained by a number of groups. Therefore, are we considering an agency that would be primarily a data service which would gather, evaluate and disseminate data and would establish the requirements for points to be observed on a continuous basis?

Rundle - The Committee need not get down to that level of specificity. One could identify the needs and spell them out in some detail; data base needs, educational needs, technology needs which might include orbits. A discussion with agencies could establish where those functions are likely to reside.

Orlin - Some reorganization of government, as proposed in an earlier report of this Committee, would be required. The agencies are trying to attack these problems through Coordinating Committees; but the problem is that they each have different priorities. For example, reobservation of stations may be a lower order priority to NASA than to NGS or USGS. The proposed study, primarily, would have to consider the organizational problem.

Rundle - You have jumped to a possible conclusion to the study. However, in discussions with agency employees, I concluded that some federal agencies would like to consider alternatives as to how these functions should be conducted, how to establish well defined functions for each agency, and how to coordinate these functions in a national program.

Strange - The difficulty with such a study would be the establishment of roles and missions for the various agencies. One would need to include the top management in each agency in such a study.

Rundle - We could define the tasks that need to be done without defining which agency would accomplish a particular task. For example, for data base management we might consider the data being obtained, the data rates needed, the structure of the data base, and what will be needed in order to interface with other data bases. The study might consider the type of orbits needed for space geodetic systems, the accuracies needed, and the means for assuring quality control.

Orlin - The two land data reports are good examples of a national need that got submerged due to interagency squabbling over roles and priorities. The reports were embraced by the civilian and local government communities; but, the federal agencies could not agree on a coordinated program. I believe that a similar result can be expected from a study on this topic. It is a national issue that should be addressed; but the likelihood that any action will be taken on any of the reports recommendations is nil.

Prescott - There are models of programs that span agencies that work quite well when each agency has a clearly defined role and each has a different part of the pie. The National Earthquake Hazard Reduction Program has parts in USGS, NSF, and FEMA.

Orlin - In the present case there aren't clearly defined roles. For a coordinated program to work, the geodetic roles of the various agencies would have to be clearly defined. Such roles would have to be established by the various agencies and agreed to through a memorandum of understanding.

Rundle - The situation is analogous to what the Committee has suggested in its current report. The Committee has made a series of recommendations; but, we have not indicated who should do the work.

Orlin - Because of our inability to assign tasks to specific agencies, the work will probably not be done. It is directly comparable to the recommendations in the land information reports. That's the problem that we need to resolve. It's not that recommendations this Committee generates are not extremely important; but, along with those recommendations we need to consider an implementation plan.

Rundle - Then how can this Committee foster such a critical national program?

Sailor - By reports similar to the one we are completing. The Committee's liaison members, using this report as a tool, need to convince their top management that such a cooperative program should be supported. Other than that there seems to be no way to get such a program started. Our report gives the liaison members an independent objective analysis of a problem that can be used for funding support.

It is clear that different niches are being carved out by the agencies. NASA expresses its role as technology development and not operational and NOAA aims to provide data to the public.

Rundle - The Erice and Coolfont documents make a strong push for NASA to assume an operational role.

Strange - That is not appreciated by the operational agencies. NOAA's role in the Global Climate Change initiative is to provide mean sea level. If, as a result of a Coolfont recommendation, NASA undertakes a similar program, NOAA would not appreciate such a recommendation. If more work is required on the sea level program, additional funds should be provided to NOAA to expand its program.

Dixon - Why did this large group of scientists decide that it was appropriate for NASA to undertake such an effort?

Strange - Is it possible that the NASA scientist grant program might have something to do with that decision?

Sailor - From what I've heard about the Coolfont meeting, I get the impression that it emphasized the things that were important to scientists. There was less interest in who would do the work. If this Committee wanted to step on more controversial ground, we could recommend who does what and make it clear that there need to be lines of division. That might be a more powerful approach than to state that the federal government should sponsor a program. In terms of national policy there has to be some division of specialization, otherwise each group will attempt to increase the size of its own program at the expense of others.

Strange - (In response to how the funding for the Global Climate Change Program was handled) The top management in each agency involved in the program determined what each agency would do. After agreeing on the level of funding for each agency, the proposal was forwarded to Congress as a single program with funding for each agency.

Orlin - That is the kind of effort that would be needed, to get the orbit program we're discussing on the right track.

Strange - That was what Miriam Baltuci was suggesting when she discussed the NRC Committee on Earth Sciences.

Rundle - Another viable topic for a panel study is the study of geodetic needs for the Global Change Program.

Orlin - It seems to me that the orbit study should be undertaken by the Committee. As the needs are diverse, input from a number of different areas will be required. In addition, we know the agencies involved and their problems and have a general idea as to their programs. A procedure for implementation of the Committees recommendations in such a study could proceed along the lines of the Global Climate Change Program.

The geodetic needs for the Global Change Program might be handled by a more cohesive group, whose expertise may not be represented on this Committee; such a situation lends itself to a panel study.

Minster - The Coolfont meeting, in my view, did not lay out a plan for NASA: but, laid out those things that should be done irrespective of who does the work. There exist the Global Change Initiative and the Concept of a Mission to Planet Earth and the scientists felt that in both of these programs that solid earth science was either neglected or the role of solid earth science was underestimated. The Coolfont recommendations are statements of what needs to be done. This idea is spread across all the Coolfont panel reports. Nevertheless, we did not recommend programs that were beyond NASA's mission: for example, a program in earthquake prediction was not recommended. However, the report addresses a program in Global Sea Level which NOAA has a mission to accomplish. The Interagency International Relation panel needs to consider such items.

Prescott - The question that arose was whether the recommendations were geared to what NASA was likely to do based upon their history or were the scientists only defining those

things that needed to be done. The Coolfont report takes a middle ground. However, the group did not consider programs that were completely outside NASA realm.

Minster - If NOAA took a stand that it would provide the Sea Level data recommended in the Coolfont report, the community should expect that NOAA would adapt or change the flavor of the program in order to satisfy not only NOAA's present mission but the needs of the community. If NOAA were not willing to do that, then it would be reasonable for the community to expect other agencies to take up the slack.

Chapman - Anyone working for a federal agency has the initial problem of trying to obtain funding. A report from a group such as this can be used as support for such funding. NGS has a further problem in that it has to compete with oceanography and meteorology programs for the hard to come by funding of NOAA. That's why the Global Climate Change Program succeeded in providing NGS with a geodetic program.

Minster - We're not considering redefining agency missions. I perceive from Saltzman's presentation that there might be a problem, if we are not careful. Someone not in favor of increased funding might conclude that the scientists attending the Coolfont meeting were feathering their own nest and stroking the back of agencies to make everyone happy. Until scientists organize to agree on those things that have to be done and who will do them, we will not have an impact.

Sailor - An interesting example is the GEOSAT mission, conceived as a geodetic mission to cover the gravity field in the oceans. It was funded by the US Navy in support of the TRIDENT program. When oceanographers became interested in GEOSAT data, that community and NORDA got behind the program. They obtained the support of university oceanographers and a broad spectrum of government agencies, who indicated a desire to use GEOSAT data to study oceanographic variability. This larger group successfully negotiated with the Navy to adjust the GEOSAT orbit to repeat every 17 days and duplicate the SEASAT orbit. As the ground tracks were essentially in the same location as those for SEASAT, the group successfully argued that this portion of GEOSAT data should be unclassified. Thus, it was the oceanography community groundswell that encouraged the agencies to cooperate in the effort. There may be other initiatives, such as a GPS mission, that require cooperation of many agencies. Strong scientific justification will be needed before agencies can develop memoranda of understanding and funding sources to accomplish such a mission. That is the kind of report Rundle is proposing. We must define the specific science needs.

Minster - Another argument for such missions is the loss of leadership in this country for quality and resolution of data. It is clear that by limiting the resolution of data required from scientific missions, particularly the data that are released to scientists, the scientific progress in this country is being slowed down. The example that is given is SPOT images; the highest resolution space photography obtainable. Investigators would prefer to use SPOT images rather than Landsat photography.

Dixon - International missions take precedence in NASA. We do not gain anything by arguing that the US must have leadership. Science is still very much international, especially as emphasis shifts to global wavelengths.

Minster - At Coolfont, we found some who wanted undertake such very short wavelength studies that the data could not be acquired from space, but had to be acquired from aircraft - topography, gravity, crustal magnetics.

Orlin - The Committee should tackle the implementation of an interagency program. The panel should tackle the geodetic needs for the Global Change Program.

Sailor - Another topic could be a discussion of the types of sensors to be used at the network stations and the coordination among existing networks such as the IRIS global

seismic network (GSN). This Committee could define the geodetic requirements and could investigate what the various organizations are doing.

? - This could include a look at what IRIS and USGS are doing on the seismic networks and recommend how the program can be coordinated.

Minster - The FLINN program has interdisciplinary and international aspects. It also must help in the study of global sea level as well as in the determination of a geodetic reference frame - stations would be established at the global sea level sites. At the same time land deformation can be measured. It has to satisfy NASA tracking requirements and provide fiducial sites for the earthquake prediction experiments

Rundle - It incorporates all of long-term problems inherent in the continuity of geodetic data.

Orlin - If we decide to undertake this study, NASA should be contacted to determine whether they plan to set up their own study group. My impression from Miriam's presentation was that they weren't. She encouraged this Committee to undertake the study.

If the Committee decides to undertake the study, a charge to the panel should be prepared and a list of proposed panel members should be developed. We could then run that past NASA, NGS, USGS and NSF, the agencies most likely to have an interest.

Minster - It might be wise to run it past the Coolfont Interagency panel. McGregor and Russ were co-chairpersons.

Dixon - Three key agencies, NASA, NGS and USGS, are represented on this Committee. Almost, de facto, we have the interagency representation that we need. We are only missing NSF.

Rundle - The FLINN concept is international in scope and transcends NASA. NASA cannot hope to run the FLINN stations all over the world. The stations established in various countries may be designated by NASA or by some international body as part of the FLINN network even though they serve other purposes.

Dixon - It is critical that there be some sort of configuration control so that the stations produce high-quality data in reasonably consistent format. An oversight or standards committee needs to be set in place.

Prescott - The problem is that for an international program there isn't one agency that has overall responsibility.

Strange - It is the station operators that establish the standards for their own stations.

Minster - We could determine the weight to be assigned to each data set.

Strange - I would object to the FLINN network setting up parallel stations, as that would not be a wise use of federal funds.

Minster - Redundant activities permit results to be compared. Is it better to have one activity and not be certain of the results or to have two activities that might confirm the results?

Strange - I am not ready to concede that the only way to get adequate GPS data worldwide is to operate a ROGUE receiver. However, that appears to be NASA's opinion so.

Minster - The FLINN network has not been defined. We should be very careful to disassociate the arguments various GPS participants have made in the past from the definition, a decade from now, of a future ideal FLINN network.

Strange - It would be more fruitful to concentrate on an ideal network to conduct the monitoring that needs to be done to satisfy the various groups using the data. The program of stations NGS is establishing is moving toward the achievement of worldwide monitoring, at the millimeter level, of mean sea level.

Minster - I take it that, if in three or four years some foreign university, after analyzing data that overlaps that of NGS, but has a different set of assumptions, states that the procedures used by NGS is not correct, that NGS would consider such an objection. If an independent set of data and/or different procedures are not available, how would one ever know how to do the analysis better?

General discussion - The data can be given to a number of different groups for analysis. NGS makes their data immediately available to any investigator. The consequence of such an attitude is that one should not try to define FLINN now. The definition would evolve as technology evolved. It is also true that if NASA defines the FLINN concept, it will be a NASA concept. It would be best for an independent group, such as this Committee, to define the concept. Coolfont raised the possibility of a FLINN network; the network was not defined in any detail. What needs to be documented are the requirements on a worldwide basis that should be coordinated, compared to the activities in the individual countries.

Strange - We know that certain fixed VLBI stations will be established. What other fixed VLBI sites are really needed beyond those that are presently planned? Given that GPS stations will be established at the planned VLBI sites, where else would one establish permanently operating GPS stations? All of the problems, presumably, have been identified at Coolfont and the number of stations required to study those problems was established. What is the priority in establishing the 200 stations recommended? There are groups planning to establish permanent stations who will be transmitting data to NGS. Which groups do we encourage the most?
One of the stations NGS is concentrating on is one in Antarctica, because that is where the glaciers exist and where the ice comes from which affect sea level.

Prescott - Before one decides where a station should be established, one needs to define what we mean by a high precision station; should it be NASA, or should an IERS type body be set up. It is not needed to determine which stations are to be let into the network, but a well defined set of standards will enable us to assess the quality of the data from each station.

Dixon - What qualifies as a good station may not be under any individuals control. Environmental effects that contribute noise, may not be detected initially; but, when detected researches do not use such stations in their analyses. A committee cannot declare, a priori, that some stations are good stations

Minster - A similar problem will plague the sea level stations along the coast. Special modeling techniques will be needed before data from these stations can be used.

General discussion - The group agreed that a set of standards and procedures would be useful. It would help observers to determine what was needed in order to achieve acceptable results. In addition, where there is a difference of opinion as to procedures and technologies, some testing program should be established. Possibly, this Committee should enunciate a set of high level goals and not be very specific as to procedures and technologies to be used.

For the FLINN network, the Committee might not want to indicate that all stations should be occupied by GPS. Possibly, the FLINN stations should be capable of being instrumented with a wide variety of instruments.

Prescott - If a network of geodetic stations is established, there would have to be some common elements. There should be a single data depository and the data should be transmitted in a common format.

General discussion - The question of a responsible agency and the problems that would be encountered for an international program were discussed. A solution, such as that used for the International Latitude Service (ILS) established under the auspices of the IUGG and the IAU, was suggested. The ILS monitored the observations from 5 stations in 4 countries. Stations did not have identical instruments - however, the observing program was identical at each station.

That is a procedure that would have to be established for an international program. Responsibility could not be placed in one federal agency. Possibly the IUGG or the IAG would take FLINN on as a special project by setting up a central bureau.

Goad - The IERS has requested proposals for a GPS service that would contribute to earth rotation studies. An equivalent program for GPS may be possible.

From an international point of view, NGS has become the focal point for orbit determinations. The problem that seems to concern us is whether NASA and NGS, acting as the responsible agent for CIGNET, will work together rather than separately.

Dixon - At our last meeting the case was made that because NASA has a tracking requirement for TOPEX, they would establish a core network to insure that they obtain the data needed.

Goad - If NASA contributes data from their stations to CIGNET, NGS can maximize the geographical coverage by putting their stations elsewhere.

Strange - For a global program such as the Global Climate Change Program which involves a number of agencies, where each agency has its own responsibility, there are certain activities related to flight missions that, if not done by NASA, will not be done. Another item is the upgrading of the capability of VLBI to higher accuracies. However, there will be a worldwide GPS orbit determination tracking network, even if NASA does not do it. The precision of the network will be as high as the users desire. Many of the components of the FLINN network can be accomplished without NASA participation; but there will not be a laser network unless NASA does the work.

Minster - The FLINN network encompasses more than GPS orbits. With a network of stations, a focus on earth science is possible. Geodesy is only one aspect of the program.

Will there be a global GPS tracking network of a reliability that will satisfy NASA's tracking needs?

Strange - NASA will have to satisfy their own requirements for their flight missions. No agency would rely on outside data which are essential for their own missions.

Minster - Should the Committee recommend that those station that will be run by NASA and those by NGS be complementary rather than redundant?

Strange - That would be worthwhile, but there are certain limitations. The three deep space stations where receivers would have to go in are at Goldstone, which is close to Mojave where a receiver is in place; Australia where only a few measurements a year will be made, which is close to Tasmania where operations will continue on a regular basis every 5 to 7 days; and Madrid, which is close to many stations operating in Europe. The alternative is to move receivers out; one possibility, if we can be assured that the data are good and that they will be made available to NGS on a continuing basis, is to take the receiver from Goldstone and place it in South America.

Minster - What the community is faced with is a requirement to have a set of stations worldwide; a subset of which is run by NASA in such as fashion that if NASA gets nothing else they can still function adequately to satisfy their missions. Similarly, NGS needs to run a set of stations so that, even if NASA does not provide any data, NGS can satisfy their missions. We should try to commingle these two sets so that the rest of the community can have its requirements satisfied.

Rundle - From our discussions I believe that the Committee should form a panel on the FLINN network. I suggest that Minster look into the procedures a panel should follow in examining this question.

ACTION - Minster to prepare a charge to the panel and recommend three or four panel members and a like number of alternates. After conferring with Roundly, Minster is to transmit the material to Orlin who will request Board approval for forming the panel.

The remainder of the session on September 13 and on September 14 dealt with the Committee Report "Geodesy in the Year 2000". After a number of revisions suggested by the Reviewers and Committee members, the Committee approved the report. Voting for approval were: Roundly, Minster, Dixon, Goad, Metzger, and Sailor. Stein was absent.

ACTION - Rundle to prepare letters to reviewers indicating how each of their comments were handled. Copies of those letters are to be transmitted to Orlin.