Report of Remotely Sensed Land Surface Properties Workshop

INPE – Cachoeria Paulista – SP

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I. Introduction

A. Purpose

The workshop had four primary objectives:

1. Identify needs of LBA for information on land surface properties.
2. Map the needs to the capabilities of current and future remote sensing systems.
3. Identify location of relevant data and develop a strategy for obtaining the data.
4. Coordinate needs for airborne missions to optimize realization of objectives.

B. Participants

A list of the participants and their addresses is attached in Appendix A.

C. Procedure

The workshop was informal with the first day devoted to brief presentations by a representative of each project present and with the second day spent preparing and discussing the content of this report. Excellent exchanges of information and perspectives occurred in a focused manner. Subsequent electronic communications were used to complete and edit this document. An overview of the report was presented at the LBA Ecology meeting in Belem in April 1999. Thorough assembly of information about remote sensing needs and proposed products from all LBA Ecology investigations with a remote sensing component was conducted via an electronic questionnaire prepared and compiled by Stefan Sandmeier (Appendix B).

D. Caveats

Within the complete scope of LBA, remote sensing is expected to be applied to studies of ecological, hydrological and atmospheric processes by many investigations. This report represents, by design and by default, only a subset of the full range of applications and investigations. The workshop was purposely focused on land surface properties primarily with ecological relevance. Although invitations were made to investigators in Brazil, USA and Europe, only one participant from Europe was able to attend, and not all teams from Brazil and the USA were present.

II. Reports of Participant Projects

The following researchers presented information related to their projects.

Presenter	Project PIs
Craig Dobson	Dobson/Soares
Greg Asner	Asner/Townsend/Bustamante
Paul Mausel	Moran/Valeriano
Marc Steininger	Mesquita/Laurance
Matthew Bobo	Potter/Carvalho
Dar Roberts	Roberts/Chadwick/Batista
John Melack	Melack/Novo
Vicki Ballester	Richey/Victoria

*Dobson -

Objective: To map the Amazon region for classification of land use and land cover change and to estimate above-ground biomass (AGB) within the limits of radar techniques. The products of the project will be a land cover classification (classes are to be determined) and AGB in coarse classes for biomass levels below about 100 Mg/ha.

Approach: Several sources of orbital radar data will be used. Orbital radar offers the advantage of signal stability. Radar has limited calibration problems and it can see through clouds. The main sources of data are SIR-C/XSAR, ERS-1/2, JERS-1, and Radarsat. Data are available from the early 1990s through the present. A number of full-region coverages are available including high water and low water coverages for 1995-96 acquired by JERS. (See Melack below).

Schedule: The Phase 1 goal is to use full resolution data from the sources mentioned above at specific sites to classify land use and then to evaluate the accuracy of the classification. Phase 1 is underway with unsupervised classification followed by scaling from full resolution to 100 m resolution and then a more sophisticated land cover classification for the focal sites. Phase 2 will fuse multiple data sources (JERS-1 and Radarsat) to provide classifications and AGB on the LBA transects. This second classification requires a new DEM. Phase 2 should be completed in approximately 2 years. Phase 3 would include a full region product, once the technique is developed; this is a large data processing task. Post-2000 new sensors such as PALSAR, Envisat, Radarsat, and LightSAR would enhance the quality of potential products and provide new opportunities for monitoring change in land cover and carbon sequestration.

Needs: Topographic data. Image processing requires a DEM in order to do the multisensor fusion. Currently, GTOPO-30 is the operational source of information. However, these data are too coarse for efficient processing of the higher resolution orbital radar data. Therefore, the group will look to the SRTM Mission to be launched in September 1999 to produce a detailed, region-wide DEM. It may be possible to request priority for the Amazon region for early processing of the SRTM topography. For preliminary data processing, the group is digitizing existing topographic maps for 5 focal sites (locations near Manaus, Santarem, Brasilia, Rondonia, and Acre).

Ground truth. A second need from this group is local expertise at 5 sites. Although the main data-set for the current project is from 1995-1996, it is still possible that low altitude aerial survey would be useful (airborne digital videography with real-time, differential GPS).

GPS. GPS base stations at the focal sites (sufficient to provide 10 m resolution as opposed to "survey quality") are highly desirable.

*Asner -

Objective: This project aims to understand climate and land-use impacts on regional biogeochemical cycles (e.g., carbon and nutrient cycles) by using a variety of data and models including remote sensing approaches. Biogeochemistry can be understood, in part, by retrieving biophysical information from remote sensing. For example, data from pastures in the Santarem region show that pasture net primary productivity (NPP) and soil nutrient fluxes correlate with the sum of standing senescent plus green vegetation retrieved from inversion of both field-based spectrometric and Landsat TM data. Handheld spectrometer data provide the best estimates of live + senescent materials, and a less certain analysis can be achieved using TM data. This approach provides a better correlation than NDVI, which cannot quantitatively resolve the senescent vegetation. Spectrometry and NPP can be closely linked to pasture management and availability of rock-derived nutrients such as P and Ca.

Phenology (temporal variation in leaf area index (LAI) and fractional photosynthetically available radiation (PAR) absorption is a key factor to understanding forest productivity as well as other biogeochemical processes such as hydrocarbon production. Retrieving phenological information at the regional (e.g., Tapajos region) to basin scale is a considerable challenge because of the potential interference of atmospheric aerosols and water vapor as well as sensor angular effects. Currently available sensors, such as the AVHRR, do not contain information to easily quantify the relative importance of vegetation phenology and atmospheric processes in the apparent time-series signal. Approximate quantification can be achieved, but may not be adequate for regional and basin-scale analyses of carbon and nutrient dynamics.

Approach: On a site basis, a 3-tier strategy is suggested for field operations: (i) Tower-based spectrometry coordinated with eddy covariance flux and biogeochemical studies. A spectrometer viewing the forest canopy would automatically acquire canopy spectra at fixed frequency. Aerosols and downwelling PAR are variables that should be measured at the towers. (ii) Intensive aircraft campaigns at key sites (towers, etc.) should be run seasonally. Optimal timing would be the end of the wet season and the end of the dry season to quantitatively assess the phenological character of forest and pasture canopies. Potential instruments critical for biophysical studies include AVIRIS and LIDAR (see aircraft section of report for further discussions). (iii) Regional data should be acquired from MODIS (full-channel, daily data) and MISR (local mode, bi-monthly) and Landsat, ASTER (at least annually) [see discussion of orbital data needs].

Needs: Critical needs of this study are a network of sites measuring aerosols along with MISR based retrieval of atmospheric aerosols. Possibly wide area coverage 4DDA models of water vapor and aerosol transport could be employed for coarse correction. Remote sensing data needs are MODIS, MISR, ASTER, and Landsat 7 TM, and seasonal aircraft-based measurements as time, weather and cost permits.

*Mausel -

Backround: Emilio Moran and his collaborators have acquired social and land use change data in several sites in the Amazon region (Tome Acu (PA), Igarape Acu (PA), Pedra (PA), Altamira (PA), and Yapu (Colombia)) for as long as 25 years. Data types include land use, soil properties, vegetation properties including regrowth rates of secondary vegetation, and household socio-economic data. A remote sensing approach to classification of secondary vegetation using Landsat TM was developed from 1992 through 1996. Three structural classes of secondary vegetation can be identified and separated with confidence using spectral signatures.

Objectives: This project will build on a seven-region study, along the LBA transects. The study will employ a nested-georeferenced approach that includes soil analysis, vegetation stand structure and composition, land use histories, institutional analyses, demography of households, and land cover classification using Landsat TM multitemporal data to understand the rates of growth of secondary vegetation. The seven regions provide a wide array of land uses and land cover along an east-to-west transect extending from the Amazon estuary and Bragantina region east of Belém near the Atlantic coast, to the Tapajós/Santarém region. This 160,000 km^2 area will be examined for land cover changes and their relation to past patterns of land use for a minimum of 25 years. The project will focus on the following goals:

A. Quantifying ecological thresholds driving structural and functional dynamics (e.g., rates of regrowth and species replacement) of secondary succession areas subjected to different land use histories across the region.

B. Generating models that incorporate socioeconomic, institutional, and demographic determinants of land use and cover change at a variety of scales.

Needs: A spectral library of land use and cover classes is needed for detailed classifications of agricultural land uses. AVIRIS scenes are needed for the focal areas and may be particularly useful for second growth biomass estimation by focusing on the "red edge" phenomenon and for accurate LAI estimates. More TM data are needed to extend the temporal range of the study. Digital videography can play a useful role in checking identifications of land surface classifications.

*Steininger -

Objectives: The Smithsonian Institution/INPA (Laurance/Mesquita) project includes a combination of field studies and computer modeling to estimate above-ground biomass in continuous forest, forest fragments, and secondary forests of different types through time and to relate these measures to remote sensing data from Landsat TM images for a modified landscape in central Amazonia. The objective is to develop a predictive model of carbon stocks and their dynamics based on readily identifiable landscape features derived from remote sensing imagery. The project will employ extensive existing data from a long-term phytodemographic project in the Amazon, coupled with additional field work, to estimate standing biomass in continuous forest plots and forest fragments. The effect of tree mortality on the edges of forest fragments is a particular focus. The project participants will develop biomass estimates for different ages and types of secondary forest, in order to assess the rate of carbon accumulation in fallow and regenerating lands following different successional trajectories.

Approach: The project requires detailed time-series of remote sensing imagery of the research landscape in the central Amazon to produce a model of carbon dynamics as a function of identifiable landscape features (e.g., fragment size and shape, and the area and age of secondary forests). The procedure for the satellite analyses will be the following:

(1) Landsat TM images will be registered to a high resolution UTM map with precision GPS data from the field; (2) image to image registration will then be performed using the base map as the reference base; (3) an unsupervised cluster classification will be run in conjunction with a knowledge-based classifier to classify the 20 x 50 km study area into 11 categories; (4) the resulting classification will be field checked and corrected where necessary for each of the satellite images used in this study, based upon reference data collected in the field using GPS, photographs, field notes, and aerial overflights; (5) the resulting classification will be "vectorized" into an ArcInfo coverage and further edited where necessary; (6) additional GIS layers of topography, river courses, roads, and biological information, including biomass estimates for each time frame, will be coregistered with the satellite data and included in the GIS; and (7) the resulting combination of the satellite classification(s) from 1982-1984-1986-1988-1990-1992-1994-1996 will be used to extrapolate the biological data spatially over the landscape.

Orbital and aircraft remote sensing work will be supplemented by ground studies of litterfall and ground based light measurements using the Licor Plant Canopy Analysis (LAI-2000) system. A future goal of the project is to develop canopy models for second growth and possibly forest edges using the SAIL and DART models.

Needs: The project requires historical and future TM imagery and possibly SPOT imagery for identification of the edge effects. Annual Landsat TM would be preferred for landscape analysis. Air photography, perhaps color-infrared may be used for detailed analysis of the forest edge effects. MODIS data may be used for phenological studies. A finer resolution approach will be needed to compare phenology of forest edges versus intact forest areas.

*Bobo -

Objectives: This report presents the study of the Potter/Carvalho team. The main tool used by this group is the daily version of CASA (Carnegie-Ames-Stanford Approach) model developed at NASA Ames Research Center, specifically for Amazon land cover/use types. Model tests will be conducted in close collaboration with experimental field studies planned for the LBA intensive research sites. The ultimate research goal is to validate model applications for different land uses at LBA sites and to scale-up regionally and dynamically the plant-soil biochemical, hydrologic, and production components of the daily NASA-CASA Amazon version, so as to more closely simulate and predict the interannual ecosystem observations from LBA.

The team will investigate the effects of changing land use in detail, through relatively high resolution (<1 km^2) model applications that focus on ecosystem production, nutrient cycling, and biogenic trace gases exchange along important eco-climatic transects and at intensive LBA study site locations. A central working hypothesis is that the quality and supply of decomposing plant material in soil is a major controller of mineralization rates and trace gas flux during and after land use change. Interacting effects of soil moisture holding capacity and canopy water relations must also be tested.

A land classification for the most perturbed area of Rondonia is being prepared. The high resolution classification (Landsat TM based) will be compared to lower resolution (AVHRR or similar) derived classifications which could be applied to drive models across the region. An important question is how much information is lost in the coarse classification.

Needs: Landsat, AVHRR and/or Seawifs (possibly MODIS) data will be needed to derive classifications and drive the CASA model. The most critical need of this group is "ground truth" for checking the classification. The classification is currently based on 1992 imagery so the validation must rely on historical data. An important question is the number of classes that should be used to drive models. Can the most important land use types for biogeochemical models be derived from Landsat or other classifications? Soil maps and other data also drive CASA. Can state and “municipio” data be used to supplement the coarse data that has been available from RADAM and other regional sources?

*Roberts -

Objectives: This project integrates remote sensing, GIS and field sampling of soil and vegetation to develop predictive models relating land cover change to its effect on nutrient cycling along the environmental gradients proposed as LBA transects. The project is based on the prediction that differences in substrate composition and environment will drive distinctly different rates of regeneration and affect the duration of pasture use, thus requiring different approaches for sustainable management. Participants will conduct time-series analysis of land-cover change using Landsat MSS and TM combined with radar to enhance discrimination of pasture and early stages of forest regeneration. The initial focus will be in Rondonia and Maraba, where historical satellite data have been assembled and analyzed, and where a large body of process-level soils and vegetation data already exist. Site selection for soil biogeochemical sampling will be driven by explicit, rule-driven mapping of terrain attributes (initially from digitized topographic maps) and land-cover and land-use maps derived from remote sensing. The long-term objective is to develop empirical and predictive biogeochemical models with a focus on nutrient dynamics linked to environmental gradients and land cover change. The models will be tested using current/future remotely sensed data sets.

Approach: The remotely sensed methodologies will build heavily on seven years of prior experience working in several areas within the Amazon basin. Participants will employ spectral mixture models using reference end-members. Through past research in the area, project participants have developed a spectral library that is applicable to much of the basin. Where new leaf level and canopy level spectra become available they will be incorporated into existing libraries.

A binary decision tree approach will be used to classify spectral mixture models from Landsat TM and MSS into at least seven classes, including primary forest, second growth, pasture, water, construction (roads/urban), recently burned, and cloud/smoke obscured. Multitemporal techniques will be used to subdivide pasture and second growth forest into age classes to establish rates of pasture maintenance and regeneration. Potential for regeneration and sustainable land use will vary as some function of intensity of pasture use and age. Images will be screened for clouds. Classification errors can be reduced through use of time series. Difficulties will occur in separating green pastures and some types of agriculture from second growth forest. This problem is expected to be particularly significant in Rondonia, which has extensive pastures, croplands and some plantations. To facilitate mapping, participants will explore use of L band radar, using SIR-C data where available (such as Rondonia) and JERS-1 in other regions.

Needs: New remotely sensed optical and microwave data sets will be needed for undersanding land use change during the LBA period. In addition, historical data would be valuable to provide finer temporal resolution in quantification of land cover transitions. AVIRIS data would be of particular value for improving land use classifications through spectral mixture models. An accuracy assessment is needed for the determinations of land cover. Aerial videography or photography may be useful for such assessments. Digitized PRODES data would be useful for comparisons of the forest/non-forest categories.

*Melack -

Objectives: This group is preparing a multi-temporal, multi-scale, multi-sensor analysis of inundation and wetland vegetation in the Amazon basin that will be linked to biogeochemical measurement and modeling activities of LBA. The remote sensing analyses will include optical (Landsat, AVHRR and EOS sensors), passive microwave (SMMR/SSMI) and active microwave (SIR-C, JERS, ERS, Radarsat) data to determine the temporally varying extent of inundation and associated vegetation. The products include (1) a synoptic, seasonal mapping of inundation and wetland vegetation structure for the Amazon basin; (2) incorporation of the inundation and vegetation data into a GIS-based database; and (3) application of results from analyses of wetland vegetation and inundation to related LBA studies of hydrological, ecological, and biogeochemical processes. The analysis is divided into 4 wetland groups: (1) main stem; (2) tributaries; (3) temporally flooded savannas; and (4) miscellaneous.

Field surveys will entail low altitude videography and surface inspections from land and water. Geolocation of flight lines and surface sites will be done with portable GPS units. The group has already collected information from the many hours of low altitude videography and field observations, as well as from published literature and from personal contacts. To improve correlations between water levels and inundation extent in wetlands distant from major rivers or gauging stations on rivers, participants will install automatic water level recorders.

Needs: Digital videography and laser altimetry should be combined on a platform for use in LBA investigations. Future Radarsat and ERS-2 acquisitions could complement the current data base. Is it possible to arrange a coordinated Radarsat data purchase?

*Ballester -

Objectives: Ballester presented a brief discussion of the project and "Carbon and Moisture Fluxes along the LBA Transects: Data Assimilation and Modeling" led by Richey/Victoria.

The research objectives are to extrapolate results and to contribute to overall biogeochemical modeling in LBA by assimilating data on carbon, nitrogen, and moisture fluxes from experimental, tower and aircraft data based on the modeling and remote sensing activities of their EOS IDS project. The participants will develop a variable-scale, drainage basin model for biogeochemical processes which includes water balances and routing (in conjunction with hydrology work elsewhere in LBA). This will require development of multi-scale digital elevation models and spatial data layers (topography, soils, land use) sufficient to evaluate 4 km, 1 km, and ultimately 30 m resolution. The enhanced hydrological models will allow implementation of more detailed consideration of the mechanistic processes and factors within the CASA model. Regional extrapolation in the overall context of biogeochemical cycling will be based on a time series of multispectral images along the LBA transects to validate and determine uncertainties in remote sensing inputs (e.g., FPAR, net solar radiation, temperature, non-photosynthetic vegetation) from image data.

Needs: The group needs an improved DEM and regional scale land use change maps for Rondonia. Precipitation data are also critical. Some precipitation estimates will probably be derived from satellite and model products.

III. Identification of Needs

A. Orbital

1. Landsat

Landsat Multispectral Scanner (MSS) imagery was acquired starting in 1973 (INPE's receiving station became operational in 1975); Landsat Thematic Mapper (TM) imagery became available in 1984, and Landsat 7's Extended Thematic Mapper (ETM) was launched in 1999. Data from these sensors provides the opportunity to document land cover and land use changes, a major aspect of LBA Ecology. Many LBA projects focused on specific sites or regions, such as Rondonia, require Landsat scenes from each year in which the data are available. Most would like one scene per year, complemented by several scenes per year occasionally to evaluate intra-annual phenology. To satisfy the overall requests will require 300 to 400 scenes depending on data quality, accessibility of data and costs. In addition, several projects request basin-wide Landsat coverage or images from subregions distributed throughout the basin; these requirements represent several hundred more scenes. All the requirements are summarized in Appendix B.

Holdings of Landsat data reside at NASA's DAAC at the Eros Data Center, at NASA's ESIP at Michigan State University, at INPE, at EOSAT, and with individual investigators. Access to data from these sources varies in cost and potential for public distribution depending on copyright agreements and other factors. A critical role of the LBA OIC is to coordinate agreements with agencies such as NASA and INPE to expedite acquisition of these data for LBA investigations. In addition, to the extent that LBA projects can share these resources, appropriate arrangements are encouraged and should be aided by the information assembled in Appendix B.

2. SAR

Synthetic aperture radar coverage of the Amazon are available for 1994 (SIR-C/X-SAR, X, C and L band, polarimetric), and 1991 to the present (JERS-1,L-HH; ERS-1/2, C-VV and Radarsat, C-HH). Next generation orbital SARs under design or construction include the European Envisat (C-band), the Canadian Radarsat 2 (C-band), the Japanese PALSAR (L-band) and the US LightSAR (L-band and maybe C- or X-band). Envisat is scheduled for launch in late 1999, and the others by 2002. All of these systems will be dual-polarization (like plus cross-polarization) and switchable between either HH or VV polarization or have full polarimetric capabilities. Thus, they will all include cross-polarization (HV). The only archival orbital SAR data for the Amazon with cross-polarization (and polarimetry) are those obtained by the Shuttle Imaging Radar (SIR-C/X-SAR) in 1994.

The nominal single-look resolution of SAR data must often be reduced via spatial averaging to an effective resolution prior to application of classification and biophysical retrieval algorithms. For archival SAR data the nominal resolutions are on the order of 10-20 m, with effective resolutions on the order of 60-100 m. The next generation of orbital SAR systems will have nominal resolution of approximately 3-10 m with effective resolutions of 10-50 m for many applications. The fine resolutions of the future systems permits the examination of local spatial variance of biophysical properties as well as sensitivity to smaller landscape patches (such as disturbance features and small agricultural plots). These effects are difficult to resolve on archival data, but should be resolvable with the next generation systems.

SAR return is very sensitive to the presence of standing water and the quantity and organization of above-ground vegetative biomass (AGB). Both the extent of inundation and the structure of wetland vegetation can be readily deciphered. Saturation of the SAR signal as AGB increases is determined by both the structural properties of the vegetation and sensor parameters of wavelength and polarization. In general, the signal saturates at about 50 t/ha, 100 t/ha and 250 t/ha for C-, L- and P-bands, respectively. HH and HV-polarizations are generally sensitive over a greater range than VV-polarization. With the exception of SIR-C/X-SAR (which only covers narrow transects over the basin), the single-polarization and frequency JERS-1 at L-band will have an effective limit of approximately 100 t/ha. While this is sufficient for study of the early stages of regrowth, it does not provide much information about the mean AGB of undisturbed forest. High quality estimates of AGB is very important to LBA.

Availability of SAR data for the Amazon basin varies among the sensors. Several SIR-C/X-SAR swaths cross the basin and are archived at the Eros Data Center. A basin-wide mosaic of JERS images for September – October 1995 and May – June 1996 is being distributed on CD ROM by JPL. Varying coverage from Radarsat, ERS and JERS exists, but the specific areas imaged, the cost, the quality and the accessibility require further examination. As for Landsat data, a concerted effort by the OIC will be required to permit access to much of these data. Holdings of LBA investigations are summarized in Appendix B.

3. SPOT

At least one research group has expressed interest in obtaining SPOT imagery to observe finer spatial patterns of canopy structure and gap distributions. Of particular interest is use of both the 20 m multispectral and 10 m panchromatic channels for detection of edge effects on forest structure and biomass. This is desirable because these edge effects have been shown to occur over 50 to 100 meters from a clearance edge. This group would desire 2 to 3 images, preferably during several dry seasons over the past 10 years, depending on image availability.

4. ASTER

Data from the ASTER instrument (onboard the EOS AM-1 platform) will prove valuable for a variety of research efforts during LBA. With its 15-90 m spatial resolution, visible-NIR-SWIR-TIR spectral coverage, and cross-track pointing (+/- 24^{o}) capability, ASTER will yield important biophysical information needed for land-cover/land-use, biophysical, and biogeochemical research. ASTER's spectral resolution alone could adequately resolve several difficult logistical issues involving high spectral resolution aircraft measurement efforts. Ten well-placed optical channels and five thermal-IR bands should provide information needed to scale from plot-level remote sensing and biophysical research efforts to the landscape and regional scales. Off-nadir pointing may prove useful for aerosol detection and surface BRDF sampling. Due to its relatively small swath width (60 km), ASTER acquisitions will be limited to intensive research sites, including the eddy covariance towers and other focused field efforts. Information and logistical channels should be opened immediately to alert ASTER management that the LBA program will need data throughout the duration of the program. LBA science teams members should be immediately polled for requests, and these requests should be sent through appropriate logistical channels for approval and planning.

5. CBERS

The Chinese-Brazilian Earth Resources Satellite (CBERS) will be launched in September 1999. It carries three cameras: (1) A 20 m resolution CCD-camera, which operates in 5 spectral bands that closely resemble the Landsat TM 5 bands, will have a repeat cycle of 26 days with a programmable option of a 3 day repeat. (2) An 80 m resolution infrared multispectral scanner, operating in 3 spectral bands (1.55 to 1.75, 2.08 to 2.35 and 10.4 to 12.5 microns), will have a 26 day repeat cycle. (3) A 260 m resolution wide field imager will operate with bands of 0.63 to 0.69 and 0.76 and 0.90 microns and have a repeat period of 4 days. The data will be distributed by INPE. Data from CBERS will be especially useful for land cover and land use change studies.

6. AVHRR, MODIS and MISR

Despite several efforts to estimate biophysical properties of vegetation (e.g., LAI, fPAR, phenology) deemed critical for large-scale biogeochemical research in the Amazon basin, significant uncertainty persists regarding the accuracy of the currently employed AVHRR sensor. Some of this uncertainty involves the inherent lack of spectral resolution and calibration of the AVHRR, but larger sources of error lie in atmospheric and orbital drift effects on estimates of plant biophysical attributes from the AVHRR (Privette et al. 1995, Tanre et al. 1992). Additional difficulties arise from the coarse resolution of the most commonly available AVHRR time-series, which are readily available only at 8 km spatial resolution (AVHRR Pathfinder; James 1994). While it is currently used to estimate certain biophysical parameters over mixed landscapes at regional to global scales, this resolution is not sufficient for estimating these attributes for specific land-cover types within patchy landscapes common in the Amazon (e.g., forest - regrowth - pasture matrices). Thus, time-series analysis and carbon cycle modeling of Amazon land covers is limited by the spatial resolution of currently available seasonal and inter-annual optical data such as the AVHRR.

While MODIS and MISR data will provide great improvement to estimation of atmospheric and surface biophysical parameters, a very valuable 17 year archive of AVHRR optical and thermal data exists which should not be ignored for LBA research efforts. A one kilometer, geometrically and atmospherically corrected product would be of value for temporal studies of specific vegetation formations over the Amazon. This should include processing of current image acquisitions and historical data throughout the 17 year archive. Of critical importance is the processing of the more recent acquisitions that are linked to studies using MODIS and MISR acquisitions. Also, SeaWifs could supplement this product to provide more cloud free images. Therefore, a 1 km AVHRR time-series from 1981 to present (and beyond) for the Amazon Basin is desirable for the LBA program.

Through some overlap in time with MODIS and MISR, increased confidence can be developed regarding the time-series trends currently found in the AVHRR record. Atmospheric and orbital drift contributions to the AVHRR record must be quantitatively, physically and consistently corrected to ensure that the best possible historical record is developed. The individual AVHRR channel data, full ephemeris (e.g., solar and viewing geometry), data quality flags, and the NDVI are required. Errors that will be involved in a "best estimate" AVHRR correction process must be propagated through the effort. Both the channel values and error ranges are critically needed for all carbon cycle, hydrological, and land-surface modeling efforts.

The forthcoming MODIS and MISR sensors, with their synergistic land-surface and atmospheric measurement capabilities, will provide a means to quantitatively address sources of uncertainty in several atmospheric (e.g., water vapor, clouds, aerosols) and land-surface (e.g., LAI, fPAR, soils, canopy architecture) parameters currently under-determined using the AVHRR sensor. The MODIS, with 36 channels and an effective spatial resolution of 0.25-4.0 km, will provide improved measurements of canopy phenology, LAI and fPAR (Running et al. 1994). Well-placed, narrow optical channels on MODIS are specifically designed for these measurements (Myneni et al. 1997). MODIS will also have the capability to estimate the presence of cirrus clouds and, to some degree, water vapor and aerosols (Kaufman et al. 1998). The high density of channels in the visible/near-infrared and two channels in the middle-IR also provide additional information on live:senescent vegetation fraction and bare soil contribution to vegetation reflectance (Asner et al. 1998). All of these variables are needed for land-cover classification, mesoscale climate/land-surface biophysical, and biogeochemical research of the Basin during the LBA program.

MISR, with four visible/near-IR channels, 9 view angles, and a spatial resolution of 0.275-1.1 km, will be co-located with MODIS on the AM-1 platform. MISR will provide unique information on atmospheric aerosols, clouds and canopy macro-structure (Diner et al. 1998). MISR's nine cameras are spaced from 70° forward to 70° aft of its orbital path, providing a unique sampling of the atmosphere and surface reflectance distribution. The angular reflectance signature of atmospheric constituents, such as biomass burning aerosols, contains critically needed information on particle properties and optical depth. MISR will likely provide the very best aerosol optical depth estimates available from a spaceborne platform, a measurement required for atmospheric radiation and chemical transport models planned for use during the LBA program. The angular reflectance distribution of all vegetation and soils is highly anisotropic. The multi-angle capability of MISR also provides access to vegetation canopy macro-structural attributes including gap fraction, crown density and spacing (Li et al. 1995, Gerard et al. 1997, Asner et al. 1998). This information is needed for improved forest classification, canopy physiological models, and mesoscale climate and land-surface biophysical models planned for use during the LBA program.

Combined, MODIS and MISR will allow simultaneous land and atmosphere parameter estimates needed for a variety of LBA efforts. These include basin-level LAI, fPAR, net primary productivity, phenology, forest stand density, aerosol loading, water vapor, cloud and cirrus cloud presence, and other parameters. These variables are needed for carbon cycle, ecosystem, hydrological and land-surface modeling efforts as well as hydrocarbon, trace gas, and other process analyses which form many of the core LBA objectives. These data will also play a major role in developing fire susceptibility analyses of vegetation.

To track time-variant biophysical and atmospheric processes and to increase the potential for cloud-free images of the Basin, MODIS and MISR data are required at full temporal resolution. For MODIS, the daily/full spatial resolution/36 channel data, with and without atmospheric correction, are required for the LBA program. MISR data are needed at the intensive LBA sites in "local mode" and throughout the Basin in "global mode". The local mode MISR data (275 m) are needed for regional analyses of atmospheric and vegetation structural properties in the Santarem, Manaus, Rondonia, and Brasilia regions (corner coordinates will be provided). In global mode (1.1 km), MISR data of the entire Amazon Basin are needed on a twice-monthly basis for seasonal and inter-annual analysis of aerosol, cloud and plant structural-phenology. Both MODIS and MISR data are needed during the entire length of LBA experiment period because quantitative analyses of seasonal and inter-annual variability of biophysical and atmospheric processes require time-series that span mesoscale and global-scale climatological processes (e.g., El Nino-Southern Oscillation). MODIS and MISR data are required continuously for a minimum of three years, and it is expected that the requirement for time-series/Basin-level data will continue as subsequent LBA activities are extended beyond the initial three year plan.

Coordination of MODIS and MISR data with Landsat ETM and ASTER acquisitions are required for the Santarem, Manaus, Rondonia, Acre, Bragantina, and Brasilia regions on at least a twice-annual basis, optimally in the early and late dry seasons in each climatically different location. This nested image acquisition strategy is required for the MODLAND validation effort (PI: A. Huete) and several investigations seeking to scale biophysical retrievals from high to low spatial resolution.

7. SeaWifs

The SeaWifs instrument on board the Seastar space craft was launched on August 1 1997. The satellite has a circular noon sun-synchronous orbit at 705 km. The sensor has an IFOV of 1.6 Mrads, or 1.13 kms. The instrument scans approximately plus-or-minus 40 degrees for the global 4 km data and 50 degrees for HRPT data. SeaWifs lacks any thermal channels but carries eight narrow (20 to 40 nm) visible and near-infrared channels (412 to 865 nm). The AVHRR has 3 thermal channels and 2 broad-band visible and near-infrared channels. The reflective bands' signal-to-noise ratio is; both are quantized to 1024 counts. SeaWifs has a bi-linear radiance sensitivity which combines high sensitivity at low spectral radiances and lower sensitivity at high spectral radiances. This may be particularly appropriate for observations of tropical forest in the visible bands.

The multiple bands in the visible allow a better specification of atmospheric aerosol conditions than is possible with AVHRR data. Thus there is potential for a more precise atmospheric correction of SeaWifs data for tropical forested areas, especially since smoke is a major issue during the dry season.

Several receiving stations include Amazonia within their range: Fundacao Universidade Rio Grande, Brazil, Comision Nacional de Actividades Espaciales, northern Argentina, Asociacion Boliviana de Teledeteccion para el Medio Ambiente, La Paz, Bolivia, and the Centro de Procesamiento de Imagenes, Caracas Venezuela.

The data are certainly of present value to the LBA teams interested in vegetation and energy patterns at 1km and coarser scales. A merging of the data with similar resolution products from AVHRR could provide ample points for smoothing/interpolation of seasonal NDVI curves. This may well be required since the basin is so cloudy that there likely will be many contaminated pixels whatever the screening method used. A combination of Seawifs and AVHRR data offers increased possibilities for LBA including fire monitoring, atmospheric correction, and smoke and haze quantification for improved NDVI retrievals.

Image data can be viewed and obtained via the SeaWifs website at http://SeaWifs.gsfc.nasa.gov. Several processing levels are available, including raw LAC and GAC and aerosol-corrected.

8. SMMR and SSMI

Continent-wide passive microwave measurements from satellites are available from 1979 to the present. The Scanning Multichannel Microwave Radiometer (SMMR) was operated from the 1979 to 1987, with global coverage every 6 days. The Special Sensor Microwave/Imager (SSMI) replaced SMMR in 1987 and operates today with 3 day global coverage. For wetland studies, the two highest frequencies, 37 GHz (SMMR and SSMI) and 85.5 GHz (SSMI only), offer the best spatial resolution (ca. 30 and 15 km, respectively). To mitigate effects of atmospheric water vapor and temperature, the difference between two polarizations are often used. The principal advantages of passive microwave measurements are their frequent coverage and their ability to reveal characteristics, such as inundation, of the land surface beneath cloud cover and vegetation.

SMMR data are readily available in gridded format expressed as polarization differences through NASA. The SSMI data are being prepared in similar forms, but all are not available as such. Only one LBA Ecology investigation is currently using these data and has access (Appendix B).

9. VCL

The Vegetation Canopy Lidar (VCL) Mission is an ESSP Mission scheduled for launch in August 2000 for a 19-month mission. The goal of VCL is characterization of the three-dimensional structure of the earth's surface. The main science objectives are (1) land-cover characterization and (2) provision of a global reference set of topographic heights. The instrument uses Nd: YAG lasers at 1,064 nm to provide 4 or 5 beams that each view a 25 m wide footprint along a near-continuous transect. Each of the transects are separated by about 2 km. VCL products will be distributed by Eros Data Center. These products include ungridded, continuous along-track observations or waveforms that provide canopy top heights, ground height, and the vertical distribution of intercepted surfaces. Gridded products will also be provided at different spatial and temporal resolutions. More details are provided at http://www.inform.umd.cdu/Geography/vcl/. The VCL data will be a valuable adjunct to SAR and electro-optical image data.

B. Aircraft

1. SAR

LBA needs for flights of airborne SAR were discussed. Three systems were considered: (1) the NASA/JPL AirSAR/TOPSAR, (2) a German commercial system operated by Aerosensing, and (3) the BioSAR operated by NASA. The AirSAR/TOPSAR system is a polarimetric SAR operating at P-, L- and C-bands on the NASA DC-8. It provides a swath of approximately 10-km in three resolution modes (20, 40 and 80 Mhz bandwidth) as well as cross-track and along-track interferometry modes. The Aerosensing SAR operates at P-band (390-450 Mhz) and X-band (9.6 Ghz) with HH polarization only. Three resolution modes are available at X-band depending upon bandwidth (2 m at 100 Mhz, 1 m at 200 Mhz and 0.5 m at 400 Mhz). BioSAR is a P-band, single polarization system that collects line transects.

Justification for airborne SAR flights is given by project needs (not prioritized) for:

- Sensor cross-calibration of archival and future orbital SAR data
- Generation of DEMs
- Resolving issues of scale and resolution,
- Above-ground biomass (AGB)
- Refining classifications.

Digital elevation models are widely needed, particularly at the main LBA sites (Manaus, Santarem, Rondonia). DEMs are largely nonexistent (except GTOPO-30 that is inadequate). SRTM-derived DEM will be of high quality for LBA, but may not be available for 2 years. An alternate plan is to use 1:250,000 or 1:100,000 topographic maps, scan to raster, convert to vector and generate DEMs. These can be cheaply done, but will be of marginal quality for many applications. The TOPSAR can provide high accuracy DEMs for these (and other) sites.

Airborne SAR flights can provide needed cross-calibration of archival orbital SAR data as well as for the next generation of orbital SARs under design or construction at the present time. Polarimetric airborne SAR data could be provided by the JPL AirSAR, but not by the other systems. The availability of such data would enable improved land-cover classification and biophysical retrieval of biomass related quantities and allow algorithm development prior to the launch of advanced, next generation orbital SAR systems. An airborne campaign could provide increased temporal resolution for studies of land-cover and biomass change. High resolution data from AirSAR or the German system will provide nominal resolutions of 1-3 m with effective resolutions on the order of 5-10 m. An airborne SAR mission could provide data as early as 2000 depending on scheduling issues, costs and permitting.

High quality estimates of AGB is very important to LBA. Provision of polarimetric SAR data (HV-polarization in particular) and P-band data could significantly enhance the quantification of AGB for the basin. In many areas, most of the biomass is contained within a small number of large trees. High resolution HV-polarization and P-band data could provide information on the number, density and size of large trees. All three airborne SAR systems considered have P-band, only the AirSAR has cross-polarization (and polarimetry). In addition, BioSAR uses a longer wavelength, implying a sensitivity over a greater range of biomass; however it is not an imager and provides only a line transect . This will make it difficult to characterize areas (2-D) and to conduct field verification (biometry) required to construct and test algorithms.

Antecedent studies using primarily AirSAR and SIR-C/X-SAR data have demonstrated the following under a variety of conditions: (1) cross-polarized data, in general, and polarimetry, in particular, lead to dramatic improvements in both the number of land-cover classes discriminated and the accuracies of the classifications, (2) P-band leads to enhanced discrimination and classification of classes with high biomass such as selectively logged areas, and (3) there is strong evidence that the phase-coherence derived from interferometric observation of tropical forests shows sensitivity to localized forest disturbance. The JPL AirSAR/TOPSAR could provide these data.

The main objectives of an airborne SAR campaign as part of LBA would be to (1) extend the range of AGB and accuracy of AGB estimates, (2) provide cross-calibration, multi-temporal continuity, and multi-resolution data to examine scaling issues, and (3) produce high quality local DEMs. Since these could all be provided by the NASA/JPL AirSAR/TOPSAR, we present a conceptual plan for such a mission.

Implementation issues relate to coverage, timing, cost and integration with ongoing LBA activities as well as issues related to exploiting the opportunity with adequate supporting measurements. Good DEMs are needed of at least the main/tower sites at Santarem, Manaus and Rondonia. High quality experiments seeking to improve AGB estimates should include areas of active (legal) logging as well as areas with undisturbed forest, and consider the availability and quality of biometry and allometric studies. These seem to be best for the sites near Manaus and Santarem where a number of collaborative opportunities exist. A rough conceptual flight pattern might be established to achieve a mosaic of 30 km by 50 km to include both the tower site and other areas of interest. This could be accomplished by 4 parallel and offset flight lines of 50 km length. If flown in a racetrack, AirSAR data could be obtained in one direction and TOPSAR data in the reverse direction. This would require on the order of 2 hours per site. At least some of the data should by obtained in a high resolution (40 or 80 Mhz) mode.

2. LIDAR

There are three routes to obtaining LIDAR data for canopy and surface topography measurements: The first option is to purchase a commercial off the shelf (COTS) rangefinder and to install it in either on a rental aircraft or Brazilian research aircraft. Profiling or 2D cross-track scanning systems are available. One example is the scanning system from Riegl USA, (their non-scanning rangefinder would work also if a long-track profile was sufficient.) Their LMS-Q140-60/80-HR (see: http://www.riegl.co.at/q140.htm) is a cross-track scanning range-finder which is delivered ready to mount, interface and fly. The vertical resolution is specified as 5 cm with an uncertainty of +/- 10 cm. The system is a first and last return system, which increases the probability of "seeing" the forest floor or understory and directly deriving tree heights. The total cross-track scan angle is 60 degrees and has a range of 500 meters for a 40% reflecting surface, the approximate reflectance for vegetation at a wavelength of 1 micron, giving a cross-track swath of 500 meters. The cross-track ground-sampling interval is 1 meter, and the laser footprint at 500 meters is only 0.5 meters. With an aircraft ground speed of 100 knots, the long-track sample spacing is ~2.2 meters. The primary drawback is the low operational altitude. If top-of-canopy measurements are sufficient, one cannot fly more than 500 meters above the canopy. If reliable returns from the organic litter on the forest floor, with a reflectance of 20%, are desired, one must fly at 350 m.

The second option for acquiring LIDAR data is to use one of NASA's, or another participating agency's, high-end systems. The following two systems are owned and operated as research grade instruments by NASA and are heavily used for other projects. These systems represent the current state-of-the-art in surface and canopy measurements. Operational price tags can be quite high, but the data are considered top-quality. One system is the LVIS (Laser Vegetation Imaging Sensor) also know as the VCL simulator. Full information and specifications can be found at the LVIS website (http://lvis.gsfc.nasa.gov/fmain.html). The LVIS uses a large footprint that receives many returns from a variety of canopy levels and records the entire return waveform thereby retaining all of the information that was available in the return signal. Good correlation between biomass derived form LVIS and that from ground measurements have been obtained. Information about the canopy layering structure is also obtainable. LVIS flies at altitudes of 4 km. Power and sensitivity levels are such that ground topography measurements can be reliably obtained. LVIS has been rebuilt to operate in smaller aircraft and could be installed in the Brazilian Airforce's Learjet or possibly on the INPE Bandeirante.

A second candidate is the NASA Airborne Topographic Mapper (ATM) (http://aol.wff.nasa.gov/aoltm.html). The ATM does not capture waveforms as a standard product, but captures up to 8 "hits" per shot, thus making much more informative measurements than rangefinders. Power levels in the ATM are such that it can fly at 700 meters and obtain reliable returns from both the forest floor and the canopy since it operates at 532 nm where the reflectance is almost equal for both surfaces. If a higher altitude is required a different laser can be used to increase the LIDAR's range. The ATM has been flown on a Twin Otter aircraft and could be flown in either of the Brazilian aircraft mentioned previously.

The third option for acquiring LIDAR data is to hire a commercial company to collect the data for LBA. Several companies have multi-hit LIDAR systems with capabilities similar to ATM and operational altitudes of 3-4 km. Given the competitive nature of the business, the prices are similar, and all provide the deployment support and post-processing to deliver a finished product. Example of potential commercial LIDAR companies include:

Terrapoint in Houston, Texas;
http://portal.admin.harc.edu/pressroom/98_0601.html

Earthdata in Hagerstown, Maryland;
http://www.earthdata.com/ednm/servdetail.htm#LIDAR

Eaglescan of Boulder, Colorado, USA; http://www.eaglescan.com/

3. Hyperspectral

Accurate land-cover characterization is a critical requirement for many of the LBA investigations. By necessity, spaceborne remote sensing will play a crucial role in scaling up detailed local measurements to larger regions across a range of temporal and spatial scales. Scaling and modeling efforts require both accurate land-cover classification and direct biophysical definition of Amazonian cover types. Airborne hyperspectral systems have the potential of making significant contributions to scaling and mapping exercises in LBA. Specific science objectives are listed below in order of priority:

1: Improved land-cover characterization

A hyperspectral system, such as AVIRIS (http://makalu.jpl.nasa.gov/aviris.html), ASAS (http://asas.gsfc.nasa.gov/asashome.html), or CASI (http://www.itres.com/casi/casi.html), would provide high quality surface reflectance for a large diversity of surface cover types and materials at an appropriate spatial and temporal scale. Reflectance retrieval algorithms for AVIRIS and ASAS are highly evolved and can, on a relatively routine basis, provide reflectance spectra with accuracies comparable to field-based spectrometers.Spectra are lacking entirely for most Amazon surfaces, or have been sampled over a restricted range of conditions and over a small (< 1 m) field-of-view. Canopy access towers, which provide some access to canopy reflectance, are still limited by the field-of-view and number of species that can be sampled. Furthermore, the scale at which a field spectrum is acquired is commonly not appropriate for coarser resolution data (e.g. 30 m Landsat TM). Examples of established research needs in which hyperspectral data can resolve current ambiguities include the capability to separate second-growth species from crops, crop identification and the accurate separation of green pasture from early second growth. These problems, while difficult from broadband systems, have demonstrated feasibility using a hyperspectral system.

In addition to direct spectral characterization, hyperspectral data can be convolved to a large number of spaceborne broad-band sensors, thereby creating spectra comparable to those that might be measured by Landsat MSS, TM, SPOT or virtually any spaceborne optical system. As a result, an airborne hyperspectral system has the potential of greatly expanding the limited spectral libraries that are available for Amazonian surface materials. Example algorithms that will benefit from such data include spectral mixture analysis and many supervised classification approaches that currently rely on a very limited number of spectra to classify Landsat TM data. Through strategic use of an airborne campaign, the number of Amazonian spectra (plant species, soil spectra, etc.) could be increased by several orders of magnitude.

2: Biophysical definition of land-cover categories

Canopy spectra are a direct product of the amount and architectural arrangement of plant components (leaves, branches, and trunks), internal leaf structure and plant chemistry. Given a large number of wavelengths, hyperspectral data can be used to define the biophysical properties of vegetation at accuracies that cannot be achieved by broadband sensors. For example, relationships have been demonstrated between the depth of the liquid water bands expressed in canopy spectra and canopy leaf area, distribution and density. Multi-angle hyperspectral data such as that collected by ASAS has been shown to correlate well with canopy architecture and thus improve classification reliability and potentially provide information about structure (Sandmeier and Deering, 1999; http://www.geo.unizh.ch/rsl2/ projects/BRDF/publications/). Furthermore, because hyperspectral systems collect images and can readily revisit sites or sample over large latitudinal gradients, they provide a critical measure of the spatial and temporal variability of biophysical properties within land-cover categories. Spatial variation is particularly important because typical classification algorithms generate a series of uniform polygons and thereby fail to quantify potentially significant within-class variation. Furthermore, detailed ground-based measurements are limited by the number of individual cover types that can be reasonably visited. A hyperspectral imaging system can provide a better measure of biophysical variation within a class or category.

3: Biophysics and spectroscopy of the phenological signal

Characterization of vegetation phenology is considered crucial to virtually all biogeochemical and hydrological modeling efforts planned for the LBA program. Hyperspectral data provide a direct measure of the manner in which the biophysical properties of land-cover categories varies phenologically (e.g,, wet and dry season). Multitemporal acquisitions of hyperspectral data would sharply improve the spectral and biophysical definition of phenological variation within land-cover categories. Two approaches have been considered for acquiring multitemporal hyperspectral data. In the first approach, a hyperspectral system could be deployed: (1) in the late dry season, when many canopies have undergone significant leaf loss; and (2) in the very early dry season, when leaves are mature and peak canopy greenness occurs. An alternate approach is to substitute time for space by a cross-latitudinal comparison of vegetation at different points in their phenology. For example, flights can be acquired over a northwest-southeast gradient across the Amazon Basin, with early dry season samples occurring in the southeast and late dry season farther to the northwest. The choice between these two strategies will depend on the availability of aircraft and sensors.

4: Improved calibration and validation of all optical data and products

A hyperspectral system can contribute to sensor calibration and validation. Surface reflectance is a vital remote sensing product from most optical sensors. One common problem of historical broadband sensor is that radiometric calibration is inadequate, and that the atmosphere is not adequately characterized to remove atmospheric contamination. Radiometric calibration of AVIRIS has evolved to the extent that it is now one of the best calibrated instruments in the scientific community. Furthermore, through detailed sampling of upwelling radiance in fine, contiguous spectral bands, AVIRIS provides an accurate measure of key atmospheric properties, of which water vapor is the most significant. When integrated with an atmospheric radiative transfer model, it is possible to retrieve surface reflectance from AVIRIS at very high accuracies. These reflectance spectra can, in turn, be used as a means of retrieving surface reflectance from broadband sensor data with poorer radiometric properties and poor atmospheric correction capabilities.

An off-nadir pointable hyperspectral system such as ASAS could contribute to better correction of such as AVHRR data. By measuring the BRDF of the surfaces with ASAS, the BRDF effects on wide scan angle data such as AVHRR can be removed or validated.

5: Baseline data for algorithm development for future spaceborne hyperspectral missions

It is likely that within the next 3-5 years spaceborne imaging spectrometry data will be available. Early analysis of hyperspectral data in tropical ecosystems in advance of such a launch will facilitate analysis of the spaceborne data. Furthermore, data from an LBA campaign would form a valuable data set for quantifying change under optimal conditions for accuracy assessment.

Outstanding Issues

Sensor platform: A hyperspectral system could be deployed on a low altitude platform, such as the Twin Otter or a high altitude platform such as the ER-2. Each has its advantages and disadvantages. A low altitude platform would be less expensive, provide improved spatial resolution (4 m) and be more flexible with regard to atmospheric conditions. In addition, it would avoid potential conflicts for the use of the ER-2. Likely targets of such a campaign would be all key study sites. A low altitude flight, however, would have the disadvantage of a small swath and low areal coverage. In addition, geometric distortion is likely to be more severe at low altitudes. In contrast, the ER-2 will provide coarser spatial resolution (20 m), may be less flexible in terms of launch windows and is more costly. However, the ER-2 would be able to cover a significantly larger number of sites and would have a greater potential for a repeat pass.

Mission duration: The optimal mission duration would be a deployment similar to SCAR-B in 1995. In the event that a shorter deployment is the only possibility, the cross-site comparison discussed above (section 3) would be required to provide a surrogate for "temporal"sampling. Given the scheduling of AVIRIS and required permissions, a 2001 deployment is considered more likely than 2000. Both ASAS and CASI have been operated on a variety of aircraft platforms including smaller aircraft and can be installed on the INPE Bandeirante. Both may be available for flights early 2000.

Alternate hyperspectral systems may be considered in lieu of AVIRIS. ASAS and CASI are such possibilities, but do not sample the water vapor region adequately and do not sample any of the middle infrared. CASI, ASAS, and many other currently available airborne hyperspectral systems do not have the spectral coverage or blue sensitivity of AVIRIS. If wavelength coverage below 430 nm and above 1000 nm is required, then a strong emphasis should be placed on the use of AVIRIS for any planned hyperspectral airborne campaign.

4. Videography

Videography has several potential applications ranging from visual interpretation of black and white, color or color infrared images derived from a commercial video camera to customized hyperspectral video systems. Three types of video systems are potentially appropriate for LBA Ecology; a differential GPS is assumed to be integrated in each, and each would fit in a small plane.

Single camera system: This system typically uses a commercial digital or analog color video camera and is flown at low altitude (e.g., 1000 m) providing ground resolution of 1 to 2 m. Swath width usually ranges from 0.5 to 2 km depending of altitude. Black and white panchromatic or color infrared versions are available. Image geometry and calibration present problems for quantitative analysis, but good spatial resolution allows accurate visual interpretation of features.

Multispectral videography: This system bundles 3 or 4 high quality digital video cameras and stores data directly in a computer. Each camera has a narrow band filter within the visible or near infrared spectrum. Typically a green, red and near infrared band are selected, but other combinations are possible, and the three band data can be analyzed using standard image processing software. However, transferring spectral signatures between scenes is problematic. The system costs $30,000 to $50,000.

Hyperspectral videography: Both hyperspectral video and hyperspectral digital camera-based systems operating in the visible and near infrared exist, but cost in excess of $100,000 and are not widely available.

C. Digital Elevation Models

Digital elevation models (DEM) are of great importance to LBA. Adequate DEMs are needed to enable terrain correction and orthorecification of a number of remote sensing data sets. Elevation models are needed for the purposes of site selection and detailed experiment planning. Knowledge of elevation and topographic variation are critical inputs for a number of process models to be used by LBA-Ecology groups. At present the only available DEM for the whole basin is the GTOPO-30; the horizontal postings and vertical accuracy are insufficient. Other existing data sources include planimetric maps at a variety of scales and accuracies; these are not universally available and many are 'out of print' and therefor difficult to obtain. In addition, they are rarely available in digital format and are thus difficult to use in an efficient manner. Topographic maps exist at scales of 1:1,000,000, 1:250,000, 1:100,000, 1:50,000. While all of the basin is covered at the coarsest scale, few of the LBA sites are covered at 1:100,000 and none at the 1:50,000 scale.

The Shuttle Radar Topography Mission (SRTM) is scheduled to be flown in September 1999. This will provide a DEM with 30 m postings and 10 m vertical accuracy for all landmasses between 57° N. and S. latitudes. The DEM is based upon single-pass, dual antenna interferometry at C-band. A subset of area (in 50-km swaths) will also be covered at higher spatial resolution using X-band interferometry. These data will be made available approximately 1 year after the flight. LBA should request the DEM and pursue the possibility of priority processing of the Amazon data. LBA should also request access to the SAR data itself and the phase coherence data.

Since the current (GTOPO-30) DEM is inadequate for LBA needs and the SRTM data set will not be available for 1 (or more) years, it is important to consider alternative, short-term solutions. The workshop considered two possibilities: (1) digitization of existing paper topographic maps at the best available scale and (2) generation of DEMs from remote sensing data (i.e., SPOT, airphotos or TOPSAR interferometry). For the first option, we propose to rasterize the best available paper maps; these could then be converted to vector data edited and converted into a DEM. Issues are (1) who has the software and capability to perform the conversion of the raster data into DEMs? and (2) what project level support is available for this process? The option of acquiring new remote sensing data for production of highly accurate DEMs was not seriously discussssed outside of the possiblity of having these generated by overflights of the NASA/JPL Topsar on the DC-8 for limited areas.

D. Ground control points

Ground control points (GCPs) are required for georectification of remotely sensed imagery and for co-location of sites sampled on the ground with imagery to allow validation of classifications.

Very few GCPs exist in the Amazon basin. GCPs can be obtained from standard maps in some cases, but in the Amazon many features change after only a few years and most maps are based on aerial photographs made in the 1970s or early 1980s. Global positioning system receivers (GPS) permit accurate location, especially if differential correction is done based on local (within 400 km) base stations. A common datum for the GCPs must be agreed upon. To be useful as GCPs for remotely sensed imagery, the features located must be apparent on the imagery.

To assess the current availability of GCPs within the Amazon a set a questions was prepared and distributed to LBA investigators, as follows:

> Do ground control points exist for your site?
> Can the ground control points be located on Landsat or JERS SAR imagery?
> What is the accuracy of the ground control points?
> Is there a GPS base station available near your site?

As LBA investigations proceed, collection of accurate GCPs using differentially corrected GPS units and explicitly tied to features locatable on appropriate imagery is of high priority.

IV. Actions

A. Questionnaire of Remote Sensing Needs

To permit implementation of a strategy to coordinate acquisition of remote sensing data and development of derived products, a questionnaire was developed for distribution to LBA investigators. A web-based version was made available from the LBA Ecology Project Office on 31 March 1999. Responses received as of July 1999 are summarized in Appendix B.

B. Questionnaire of GCP Availability

To assess the availability of GCPs among LBA investigators a web-based questionnaire was distributed on 31 March 1999 from the LBA Ecology Project Office. Responses received as of July 1999 are summarized in Appendix B.

C. Aerial Videography (May-June 1999)

As part of the validation of the land cover and inundation classification being done with the basin-wide JERS SAR data, a flight of the INPE Bandeirante occurred in June 1999. Although focused on riverine corriders and floodable savannas, the flight lines permitted coverage of most LBA sites. Tentative flight lines were identified at the workshop, and refinements discussed at the LBA Ecology meeting in April 1999. Final flight lines were established during May 1999. An important lesson from this planning exercise was its complexity and the necessity to request from each investigator a set of way points for their flight lines in the same coordinate system.

The aircraft carried digital video cameras with continuous recording of differentially corrected GPS coordinates marked on the video tapes. Spatial resolution varied as a function of altitude, but a resolution of 1 to 2 m was normal. For selected transects, a LIDAR was operated to permit canopy structure and tree height measurements. The aircraft required a pilot, co-pilot and navigator, and the basic equipment required two operators. Three additional people were sometimes accommodated for the purpose of making observations and/or obtaining hand-held videography or photography.

V. Recommendations

A. Training (Tutorial and Workshop)

The discussion of approaches to train students in understanding and applying remote sensing techniques to ecological questions reflected the considerable experience at INPE and other institutions represented among the participants. Three types of training were recommended:

1. Development of a training module, probably to be distributed on a CD-ROM, to be used as a self-paced course.
2. Recommend enrollment in a full course of study such as the Masters programs offered at INPE.
3. Development of a focused short course, i.e., two weeks, concerned with one or two specific activities. For example, a course devoted to use of digital videography may be useful.

Based on recent experience at INPE with an attempt to cover remote sensing in two weeks as part of a larger course on earth system science, it was the consensus that it was not possible to do justice to theory or applications in so short a period.

B. Involvement of more participants

Several suggestions were offered to encourage increased involvement of additional investigators with complementary expertise. Greater participation by European scientists with interests in applying remote sensing to ecological questions would be a benefit to LBA. The strong European effort associated with land use and land cover change and its socioeconomic aspects would strengthen LBA. As funding arrangements become apparent, appropriate studies should be fostered.

C. Intercomparison of data products and validation

Although the examples concern land-cover classification, the same issues apply to the comparison of methodologies for estimating surface biophysical properties, e.g. biomass or NPP.

1. Agreement on land cover class definitions:

An agreement on a terminology is essential, e.g., abandoned or degraded pasture vs. early secondary regrowth.. Class definitions are essential to provide a basis for comparison among groups. There are several existing land cover products which may help, e.g., IBGE .

2. Development of an assessment plan:

A scheme for pooling validation data from various projects is required. A standard geographic framework, i.e., a common datum for all GPS surveys, is an essential component; the South American Provisional is recommended. Furthermore, an operational LBA DIS is critical for a successful assessment plan.

3. Comparison of methodologies:

Multiple approaches are implicit in having several different groups mapping the same areas, but necessitates intercomparisons of methodologies.

4. Fusion of output products:

It is probable that some maps will be better in some areas, while others are better elsewhere. An example is the strategy of one group applying SAR to wetlands and another to uplands. These two classifications should be combined or fused into a single product.

5. Regional extrapolation:
A central issue in extrapolation is whether spectral relationships within vegetation are consistent throughout the entire Amazon. However, few groups have proposed to address the comparison of such relationships among different areas within the basin. For example, several groups will explore the relationship between canopy reflectance and canopy structure of secondary forests. While there is evidence for common trends in canopy reflectance with regrowth, there are most likely significant differences in the specific relationships among study sites and seasons of image acquisition. Some organization in the inter-comparison of such relationships is needed. Linked to this should be efforts at modeling expected differences in responses of satellite data under different conditions. Again, while different methods of satellite data analysis are encouraged, the application of some standard classification methods conducted in each study area would help in assessing under what conditions various surface conditions can best be estimated.

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Appendices

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B. Results of remote sensing data needs and products questionnaire

A summary of the results from the remote sensing data needs and products questionnaire performed by the Project Office is listed in the attached table. The information is divided into available and requested remote sensing data sets.

	Team ID	US-PI	Contact person	Contact email	Platform	Sensor	Data availability	Priority	Study area	Southern-most latitude	Northern-most latitude	Western-most longitude	Eastern-most longitude	Start path	End path	Start row	End row	Start date
1	LC-07	Melack	Laura Hess	lola@icess.ucsb.edu	ENVISAT	multiple	Available		Amazon Basin									
2	LC-06	Huete	Alfredo Huete	ahuete@ag.arizona.edu	ER-2	AVIRIS	Available		Ji-Parana, Porto Velho, Alta Floresta, Cuiaba, Brasilia, Campo Grande	-10.7	-5.5	-61	-49					16-Aug-95
3	CD-07	Smith	Eric A. Smith	esmith@metsat.met.fsu.edu	GOES-8	Imager	Available		Amazon Basin	-15	5	-75	-40					1-Mar-98
4	LC-07	Melack	John Melack	melack@lscf.ucsb.edu	INPE Bandeirante	Analog and digital video, geocoded	Available		Amazon Basin - Brazilian part									
5	LC-07	Melack	John Melack	melack@lscf.ucsb.edu	JERS-1	SAR	Available		Amazon Basin	-15	10	-83	-45					27-Sep-95
6	LC-07	Melack	John Melack	melack@lscf.ucsb.edu	JERS-1	SAR	Available		Amazon Basin	-15	5	-80	-50					1-May-96
7	LC-11	Freeman	Bruce Chapman	bruce.chapman@jpl.nasa.gov	JERS-1	SAR	Available		Amazon Basin	-15	10	-83	-45					27-Sep-95
8	LC-07	Melack	John Melack	melack@lscf.ucsb.edu	JERS-1	SAR	Available		Solimoes floodplain, Cabaliana-Manacapuru region	-3.66	3	-61.5	-60.16	415	416	306	306	
9	LC-02/ CD-05/ CD-11/ ND-02	Brown/ Nepstad/ Houghton/ Davidson	Tom Stone	tstone@whrc.org	Landsat	MSS	Available		Amazon Basin					224	231	62	72	1-Jan-72
10	LC-02/ CD-05/ CD-11/ ND-02	Brown/ Nepstad/ Houghton/ Davidson	Tom Stone	tstone@whrc.org	Landsat	MSS	Available		Amazon Basin					4	5	66	69	1-Jan-75
11	ND-01	Chadwick/ Roberts	Dar Roberts	roberts@geog.ucsb.edu	Landsat	MSS	Available		Amazon Basin					2	251	57	72	6-Sep-72
12	LC-10	Skole	walter chomentowski	whc@bsrsi.msu.edu	Landsat	MSS	Available		Amazon Basin	-20	5	-80	-50					1-Jan-72
13	ND-01	Chadwick/ Roberts	Dar Roberts	roberts@geog.ucsb.edu, kiedman@geog.ucsb.edu	Landsat	TM	Available		Amazon Basin	-18	4	-75	-40	1	233	53	73	24-Jun-84
14	LC-09	Moran	Eduardo Brondizio	ebrondiz@indiana.edu	Landsat	TM	Available		Altamira, Brasil					226		62		4-Aug-85
15	LC-02/ CD-05/ CD-11/ ND-02	Brown/ Nepstad/ Houghton/ Davidson	Tom Stone	tstone@whrc.org	Landsat	TM	Available		Amazon Basin					1	6	63	69	1-Jan-86
16	LC-02/ CD-05/ CD-11/ ND-02	Brown/ Nepstad/ Houghton/ Davidson	Tom Stone	tstone@whrc.org	Landsat	TM	Available		Amazon Basin					222	233	61	72	1-Jan-84
17	LC-10	Skole	walter chomentowski	whc@bsrsi.msu.edu	Landsat	TM	Available		Amazon Basin	-20	5	-80	-50					1-Jan-84
18	LC-06	Huete	Alfredo Huete	ahuete@ag.arizona.edu	Landsat	TM	Available		Ji-Parana, and Maraba	-10.7	-5.5	-61	-49					10-Jul-92
19	LC-09	Moran	Eduardo Brondizio	ebrondiz@indiana.edu	Landsat	TM	Available		Machadinho d'Oeste, Vale do Anari, Rondonia, Brasil					231		67		23-Jun-86
20	LC-09	Moran	Eduardo Brondizio	ebrondiz@indiana.edu	Landsat	TM	Available		Ponte de Pedras, Marajo island, Brasil					224		61		21-Jul-85
21	LC-09	Moran	Eduardo Brondizio	ebrondiz@indiana.edu	Landsat	TM	Available		Ponte de Pedras, Marajo island, Brasil					224		61		20-Sep-84
22	LC-09	Moran	Eduardo Brondizio	ebrondiz@indiana.edu	Landsat	TM	Available		Ponte de Pedras, Marajo island, Brasil					224		61		24-Jul-92
23	LC-09	Moran	Eduardo Brondizio	ebrondiz@indiana.edu	Landsat	TM	Available		Santarem, Middle Valley of the Amazon River, Brasil					227		62		29-Jul-86
24	LC-09	Moran	Eduardo Brondizio	ebrondiz@indiana.edu	Landsat	TM	Available		Santarem, Middle Valley of the Amazon River, Brasil					227		62		9-Aug-90
25	LC-09	Moran	Eduardo Brondizio	ebrondiz@indiana.edu	Landsat	TM	Available		Santarem, Middle Valley of the Amazon River, Brasil					227		62		10-Oct-95
26	LC-09	Moran	Eduardo Brondizio	ebrondiz@indiana.edu	Landsat	TM	Available		Tome-Acu region, southeast of Belem, Brasil					223		61		16-Sep-85
27	LC-09	Moran	Eduardo Brondizio	ebrondiz@indiana.edu	Landsat	TM	Available		Yapu, Colombia					5		59		7-Sep-90
28	LC-07	Melack	Leal Mertes	leal@geog.ucsb.edu	Landsat 4/5	TM	Available		Amazon Basin - mainstem Amazon River floodplain									1-Jan-88
29	LC-01	Bilsborrow	Brian Frizzelle	brian_frizzelle@unc.edu	LANDSAT 4/5	TM	Available		The Oriente, northeast Ecuador					8	9	60	61	16-Dec-84
30	EOS		Jeff Morisette	jeff.morisette@gsfc.nasa.gov	Landsat 7	ETM+	Available		Ji-Parana	-10.22	-10.22	-61.89	-61.89	231		67		1-Aug-99

	Team ID	End date	Repetition rate	Process-ing level	Bands	Cloud cover	Pro-jection	Flight altitude	Pro-jection datum	GCP number	GCP for Landsat/TM	GCP for JERS SAR	GCP accu-racy in m	GPS base station availability	Ground valid. plans	Date posted	Comments
1	LC-07			0		0				none	Unknown	Unknown	unknown	Unknown	No	12-Apr-99	Multiple sensors, resolutions and study sites. First data available in 2001.
2	LC-06	7-Sep-95		0		0		30,000 feet		none	Unknown	Unknown	unknown	Unknown	Yes	9-Apr-99	This is the 1995 Smoke, Clouds, and Radiation Experiment (SCAR-B). All AVIRIS scenes are archived and well documented at NASA/JPL.
3	CD-07	29-Feb-00	0.5 or 3 hourly	0	5 bands	0	GOES perfect			none	Unknown	Unknown	unknown	Unknown	No	13-Apr-99	
4	LC-07			0		0				none	Unknown	Unknown	unknown	Unknown	No	12-Apr-99	Two surveys, Sep/Oct 1997 and May/June 1999. Mosaics of video strips will be made available on web site for selected areas.
5	LC-07	12-Dec-95		1b	L-HH	0	Geogra-phic		WGS-84	53	Yes	Yes	+/- 100	No	No	12-Apr-99	See southport.jpl.nasa.gov/amazon for further information including release schedule for CD-ROMs.
6	LC-07	1-Jun-96		1b	L-HH	0	Geogra-phic		WGS-84	53	Yes	Yes	+/- 100	No	No	12-Apr-99	See southport.jpl.nasa.gov/amazon for further information including release schedule for CD-ROMs.
7	LC-11	12-Dec-95		1b	L-HH	0	Mercator		GEM6	52	Unknown	Yes	100	Unknown	Yes	1-Apr-99	100 m ground resolution, mosaicked JERS-1 data. Produced with the Global Rain Forest Mapping project (GRFM). Data is available on CD-ROM. Second coverage (May-Aug 1996) is expected to be produced during 1999.
8	LC-07			1b	L-HH	0	UTM		GRS-80	53	Yes	Yes	+/- 100	No	No	12-Apr-99	Seven dates from 1993 to 1996.
9	LC-02/ CD-05/ CD-11/ ND-02	1-Jan-81								none	Unknown	Unknown	unknown	Unknown	No	3-May-99	13 scenes
10	LC-02/ CD-05/ CD-11/ ND-02	1-Jan-86								none	Unknown	Unknown	unknown	Unknown	No	3-May-99	5 scenes
11	ND-01	8-Aug-87		0		0				none	Unknown	Unknown	unknown	Unknown	No	20-Apr-99	Actual List of MSS Scenes available
12	LC-10	1-Jan-92		1a		0	UTM		WGS84	100	Yes	Unknown	50	Unknown	No	25-May-99	Please check the Tropical Rain Forest Information Center at www.bsrsi.msu.edu to browse and purchase ($25/scene) Landsat imagery from the Brazilian Amazon.
13	ND-01	30-Jul-97		0		0				none	Unknown	Unknown	unknown	Unknown	No	20-Apr-99	Actual Scene List Available.
14	LC-09	15-Jun-96		1b	bands 1-7	0				unknown	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	Landsat TM imagery available for the dates: 1985/08/04, 1988/07/11, 1991/07/20 and 1996/06/15. Digital maps at 1:500,000 derived from interpretation of analogic Landsat MSS images are available for 1973, 1975, 1976 and 1979.
15	LC-02/ CD-05/ CD-11/ ND-02	1-Jan-92								none	Unknown	Unknown	unknown	Unknown	No	3-May-99	19 scenes
16	LC-02/ CD-05/ CD-11/ ND-02	1-Jan-92								none	Unknown	Unknown	unknown	Unknown	No	3-May-99	71 scenes
17	LC-10	1-Jan-92		1a		0	UTM		WGS84	100	Yes	Unknown	50	Unknown	No	25-May-99	Please check the Tropical Rain Forest Information Center at www.bsrsi.msu.edu to browse and purchase ($25/scene) Landsat imagery from the Brazilian Amazon.
18	LC-06	10-Aug-92		0		0				none	Unknown	Unknown	unknown	Unknown	Yes	9-Apr-99	This is a small part of a 1992 wall-to-wall TM coverage over Brazil. Please see CJ Tucker.
19	LC-09	18-Jun-98		1b	bands 1-5, 7	0				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	Four images available for: 1986/06/23, 1988/07/28, 1994/07/15 and 1998/06/18.
20	LC-09	22-Jul-91		1b	bands 1-7	0				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	Four images, for: 1985/07/21, 1987/10/15, 1988/08/14 and 1991/07/22.
21	LC-09			1b	bands 1-7	4				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	
22	LC-09			1b	bands 1-5	3				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	
23	LC-09			1b	bands 1-5, 7	1				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	
24	LC-09			1b	bands 1-5, 7	4				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	
25	LC-09			1b	bands 1-5, 7	3				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	
26	LC-09	13-Jun-91		0	bands 1-5, 7	0				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	Two images, both with less than 10% cloud cover.
27	LC-09	16-Jan-92		1b		0				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	Three images available, for: 1990/09/07, 1991/12/08 and 1992/01/16. The cloud cover on 1991/12/08 is approximately 50-60%. For the other dates cloud cover is less than 10%.
28	LC-07	1-Jan-94		0		0				none	Unknown	Unknown	unknown	Unknown	No	31-Mar-99	In colloboration with E. Novo and T. Krug at INPE, we have assembled a complete Landsat mosaic of the entire floodplain of the mainstem Amazon River in Brazil. The mosaicked images have been classified into wetlands classes.
29	LC-01	6-Sep-97		1b	Bands 1-7 for all data sets	0	UTM		NAD27, NAD83, WGS84	none	Unknown	Unknown	unknown	Unknown	Yes	1-Apr-99	We have a total of 19 Landsat TM scenes: P8R60(7); P8R61(4); P9R60(5); P9R61(3). They are all in UTM projection, but the datums vary depending on data set among the three datums listed above.
30	EOS		90	1b		0				none	Unknown	Unknown	unknown	Unknown	No	1-Apr-99	"have available" here means that we are making plans to have this available. The submission is for the ETM+ data acquisition associated with each of the EOS Land Validation Core Sites. These subsets will includ all L3 and L4 MODIS Land products.

	Team ID	US-PI	Contact person	Contact email	Platform	Sensor	Data availability	Priority	Study area	Southern-most latitude	Northern-most latitude	Western-most longitude	Eastern-most longitude	Start path	End path	Start row	End row	Start date
31	EOS		Jeff Morisette	jeff.morisette@gsfc.nasa.gov	Landsat 7	ETM+	Available		Tapajos	-2.86	-2.86	-54.96	-54.96	227		62		1-Aug-99
32	DAAC		James McManus	mcmanus@daac.gsfc.nasa.gov	NOAA	AVHRR	Available		Amazon Basin	-15	15	-80	-40					
33	LC-06	Huete	Alfredo Huete	ahuete@ag.arizona.edu	NOAA	AVHRR	Available		South America									1-Jan-89
34	LC-07	Melack	John M. Melack	melack@lifesci.ucsb.edu	Radarsat-1	Radarsat-1 scansar wide beam	Available		Amazon Basin	-21	5	-79.5	-45.5					1-Dec-96
35	LC-07	Melack	John M. Melack	melack@lifesci.ucsb.edu	Radarsat-1	Radarsat-1 scansar wide beam	Available		Amazon Basin	-21	5	-79.5	-45.5					1-Mar-97
36	LC-07	Melack	John M. Melack	melack@lifesci.ucsb.edu	Radarsat-1	Radarsat-1 scansar wide beam	Available		Amazon Basin	-21	5	-79.5	-45.5					1-Jul-97
37	LC-07	Melack	John M. Melack	melack@lifesci.ucsb.edu	Radarsat-1	Radarsat-1 scansar wide beam	Available		Amazon Basin	-21	5	-79.5	-45.5					1-Mar-98
38	LC-06	Huete	Alfredo Huete	ahuete@ag.arizona.edu	SeaStar	SeaWiFS	Available		South America									17-Sep-97
39	LC-07	Melack	John Melack	melack@lscf.ucsb.edu	SIR-C	SAR	Available		Amazon Basin	-15	5	-80	-50					1-Apr-94
40	EOS		Jeff Morisette	jeff.morisette@gsfc.nasa.gov	Space Imaging	IKONOS	Available		Ji-Parana	-10.22	-10.22	-61.89	-61.89					1-Jan-00
41	EOS		Jeff Morisette	jeff.morisette@gsfc.nasa.gov	Space Imaging	IKONOS	Available		Tapajos	-2.86	-2.86	-54.96	-54.96					1-Jan-00
42	LC-09	Moran	Eduardo Brondizio	ebrondiz@indiana.edu	SPOT	PAN	Available		Machadinho d'Oeste, Vale do Anari, Rondonia, Brasil					678	368	L23.8		26-May-95
43	EOS		Jeff Morisette	jeff.morisette@gsfc.nasa.gov	Terra	ASTER	Available		Ji-Parana	-10.72	-9.72	-62.39	-61.39					1-Jan-00
44	EOS		Jeff Morisette	jeff.morisette@gsfc.nasa.gov	Terra	ASTER	Available		Tapajos	-3.36	-2.36	-55.46	-54.46					1-Jan-00
45	LC-06	Huete	Alfredo Huete	ahuete@ag.arizona.edu	Terra	MODIS	Available		Amazon Basin									1-Jan-00
46	EOS		Jeff Morisette	jeff.morisette@gsfc.nasa.gov	Terra	MODIS	Available		Ji-Parana	-10.22	-10.22	-61.89	-61.89					1-Jan-00
47	EOS		Jeff Morisette	jeff.morisette@gsfc.nasa.gov	Terra	MODIS	Available		Tapajos	-2.86	-2.86	-54.96	-54.96					1-Jan-00
48	DAAC		James McManus	mcmanus@daac.gsfc.nasa.gov	TRMM	TRMM	Available		Amazon Basin	-15	15	-80	-50					
49	CD-06	Richey	Stephanie Bohlman	steph@rad.geology.washington.edu	airborne multi-spectral, MODIS, TM		Requested	Critical	Amazon Basin, more detailed study at LBA tower sites									1-Sep-99
50	LC-01	Bilsborrow	Brian Frizzelle	brian_frizzelle@unc.edu	Any, with preference on Landsat, SPOT, IRS, and RADARSAT or other radar data	Landsat TM, SPOT Multispectral and Pan	Requested	Important	Northeast Ecuador	-5	1	-81	-72					1-Jan-99
51	LC-08	Moore	Xiangming Xiao	xiangming.xiao@unh.edu	EO-1	ALI	Requested	Desirable	LBA-Ecology tower sites - all									
52	LC-08	Moore	Xiangming Xiao	xiangming.xiao@unh.edu	EO-1	Hyperion	Requested	Desirable	LBA-Ecology tower sites - all									
53	ND-10	Townsend	Greg Asner	gpa@pangea.stanford.edu	ER-2	AVIRIS	Requested	Important	Tapajos region (FLONA and eastern ranches)									1-Jun-00
54	LC-04	Foley	Jon Foley	jfoley@facstaff.wisc.edu	GOES		Requested	Important	Amazon Basin and Tocantins Basin									
55	LC-08	Moore	Xiangming Xiao	xiangming.xiao@unh.edu	JERS-1	SAR	Requested	Desirable	LBA-ecology tower sites - all									1-Mar-96
56	TG-05	Potter	Chris Potter/Matt Bobo	cpotter@mail.arc.nasa.gov	JERS-1	SAR	Requested	Critical	Rondonia					230	232	66	69	1-Jul-99
57	TG-05	Potter	Chris Potter/Matt Bobo	cpotter@mail.arc.nasa.gov	JERS-1	SAR	Requested	Critical	Santarem					225	227	62	63	1-Jul-99
58	LC-04	Foley	Jon Foley	jfoley@facstaff.wisc.edu	Landsat	TM	Requested	Critical	Amazon Basin and Tocantins Basin									
59	LC-10	Skole	walter chomentowski	whc@bsrsi.msu.edu	Landsat	TM	Requested	Desirable	Amazon Basin	-20	5	-80	-40					1-Jun-86

	Team ID	End date	Repetition rate	Process-ing level	Bands	Cloud cover	Pro-jection	Flight altitude	Pro-jection datum	GCP number	GCP for Landsat/TM	GCP for JERS SAR	GCP accu-racy in m	GPS base station availability	Ground valid. plans	Date posted	Comments
31	EOS		90	1b		0				none	Unknown	Unknown	unknown	Unknown	No	1-Apr-99	"have available" here means that we are making plans to have this available. The submission is for the ETM+ data acquisition associated with each of the EOS Land Validation Core Sites. These subsets will includ all L3 and L4 MODIS Land products.
32	DAAC															7-May-99	EOS DAAC
33	LC-06	30-Dec-89	1	0		0				none	Unknown	Unknown	unknown	Unknown	No	9-Apr-99	Daily , 8km resolution for 1989; and also as 16-day composites of red, NIR, and NDVI
34	LC-07	28-Feb-97		0	C HH	0	na	na	na	none	Unknown	Unknown	unknown	Unknown	No	13-Apr-99	
35	LC-07	30-Jun-97		0	C HH	0	na	na	na	none	Unknown	Unknown	unknown	Unknown	No	13-Apr-99	
36	LC-07	30-Sep-97		0	C HH	0	na	na	na	none	Unknown	Unknown	unknown	Unknown	No	13-Apr-99	
37	LC-07	30-Jun-98		0	C HH	0	na	na	na	none	Unknown	Unknown	unknown	Unknown	No	13-Apr-99	
38	LC-06	14-Oct-97	1	0		0				none	Unknown	Unknown	unknown	Unknown	No	9-Apr-99	Need permission for use of this data. 8km resolution
39	LC-07	31-Oct-94		1b	C,L quad-pol	0					Unknown	Unknown		Unknown	No	12-Apr-99	All unique SIR-C datatakes over Amazon basin.
40	EOS			1b		0				none	Unknown	Unknown	unknown	Unknown	No	1-Apr-99	"have available" here means that we are making plans to have this available. The submission is for the Science Data Buy requests associated with each of the EOS Land Validation Core Sites. This will be one IKONOS scene (11km x 11 km).
41	EOS			1b		0				none	Unknown	Unknown	unknown	Unknown	No	1-Apr-99	"have available" here means that we are making plans to have this available. The submission is for the Science Data Buy requests associated with each of the EOS Land Validation Core Sites. This will be one IKONOS scene (11km x 11 km).
42	LC-09			1b	PAN	0				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	
43	EOS	1-Jan-05	50	1b		0				none	Unknown	Unknown	unknown	Unknown	No	1-Apr-99	"have available" here means that we are making plans to have this available. The submission is for ASTER data requests associated with each of the EOS Land Validation Core Sites. The ASTER request are one degreee by one degree centered on the Lat./Lon
44	EOS	1-Jan-05	50	1b		0				none	Unknown	Unknown	unknown	Unknown	No	1-Apr-99	"have available" here means that we are making plans to have this available. The submission is for ASTER data requests associated with each of the EOS Land Validation Core Sites. The ASTER request are one degreee by one degree centered on the Lat./Lon
45	LC-06		16	0		0				none	Unknown	Unknown	unknown	Unknown	Yes	9-Apr-99	As part of our proposal to LBA, MODIS data products will be provided, mostly on a 16 day periodic basis at both 250m and 1 km resolution. Includes, surface reflectance, vegetation indices, albedo, LST, fire, land cover/ change, BRDF, LAI/fAPAR, and NPP.
46	EOS			0		0				none	Unknown	Unknown	unknown	Unknown	No	1-Apr-99	"have available" here means that we are making plans to have this available. The submission is for the MODIS Subset data associated for each of the EOS Land Validation Core Sites. These subsets will includ all L3 and L4 MODIS Land products.
47	EOS			0		0				none	Unknown	Unknown	unknown	Unknown	No	1-Apr-99	"have available" here means that we are making plans to have this available. The submission is for the MODIS Subset data associated for each of the EOS Land Validation Core Sites. These subsets will includ all L3 and L4 MODIS Land products.
48	DAAC															7-May-99	EOS DAAC; Is there an interest for getting TRMM data for 40W - 50W?
49	CD-06	1-Sep-01	>1 per wet season dry season images for TM and aircraft data, 1 per month for MODIS	1a	visible, near and mid infrared	0		300 and 2000 m		none	Yes	Unknown	unknown	Unknown	Yes	7-Apr-99	We are interested in defining seasonal changes on a regional level in the Amazon basin, using a multiple scale approach. We plan on obtaining high frequency multispectral data from instruments mounted on LBA towers.
50	LC-01			1b	All available	0	UTM		WGS84	none	Unknown	Unknown	unknown	Unknown	No	1-Apr-99	We request any available cloud-free data for the above geographic coordinates beginning in January of 1999 and continuing until July 2001.
51	LC-08			0		0				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	
52	LC-08			0		0				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	
53	ND-10	30-Nov-02		1a	all optical channels	1		20 km		30; many more planned	Unknown	Unknown	< 12	Unknown	Yes	6-Apr-99	A single, major aircraft campaign is needed, and I suggest that it take place in the dry season of 2001.
54	LC-04			3		0				none	Unknown	Unknown	unknown	Unknown	No	8-Jun-99	We would like to get any information about fire detection that this sensor can provide.
55	LC-08	1-Apr-98		0		0				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	
56	TG-05	1-Sep-99		1b	all	0			south american provisional 1969	15	Yes	Yes	100,000 scale	Unknown	Yes	31-Mar-99	Interested in dry-season Landsat-5 data for the same area in 1995 or 1996. We are interested in 8 scenes covering the majority of the area undergoing active land-use change in Rondonia.
57	TG-05	1-Sep-99		1b	all	0			south american provisional 1969	0	Unknown	Unknown		Unknown	Yes	31-Mar-99	Interested in dry-season Landsat-5 data for the same area in 1995 or 1996. We are interested in 6 scenes covering the majority of the area undergoing active land-use change in Para. Interested in wet and dry season JERS data.
58	LC-04			3		0				none	Unknown	Unknown	unknown	Unknown	No	7-Jun-99	We are looking for the deforestation map developed by D. Skole and C. Tucker 1993 for the Brazil using Landsat TM data set and a GIS for 1978 and 1988. We will also use the equivalent of this data set for the rest of the Amazon basin.
59	LC-10	1-Oct-99		1a		0	UTM		WGS84	100	Yes	Unknown	50	No	Yes	25-May-99	

	Team ID	US-PI	Contact person	Contact email	Platform	Sensor	Data availability	Priority	Study area	Southern-most latitude	Northern-most latitude	Western-most longitude	Eastern-most longitude	Start path	End path	Start row	End row	Start date
60	ND-01	Chadwick/ Roberts	Dar Roberts	dar@geog.ucsb.edu	Landsat	TM	Requested	Important	Rondonia, Brazil	-14	-8	-65	-58	229	232	66	69	25-May-93
61	ND-10	Townsend	Greg Asner	gpa@pangea.stanford.edu	Landsat 4,5,7	TM	Requested	Desirable	Tapajos Region, south of Santarem					227	227	62	63	1-Jan-84
62	ND-10	Townsend	Greg Asner	gpa@pangea.stanford.edu	Landsat 4,5,7	TM	Requested	Critical	Tapajos Region, south of Santarem, all of FLONA-Tapajos and eastern ranches					227	227	62	63	1-Jan-84
63	ND-10	Townsend	Greg Asner/Michael Keller	gpa@pangea.stanford.edu	Landsat 4,5,7	TM, ETM+	Requested	Critical	Cauaxi					227	227	62	62	1-Jan-84
64	LC-05	Laurence	Marc Steininger	marc@surutu.gsfc.nasa.gov	Landsat 4/5	TM	Requested	Critical	Manaus		-62			231	231	62	62	21-Sep-84
65	LC-08	Moore	Xiangming Xiao	xiangming.xiao@unh.edu	Landsat 7	ETM+	Requested	Desirable	LBA-Ecology tower sites - all									
66	TG-05	Potter	Chris Potter/Matt Bobo	cpotter@mail.arc.nasa.gov	Landsat 7	ETM+	Requested	Critical	Rondonia					230	232	66	69	1-Jul-99
67	TG-05	Potter	Chris Potter/Matt Bobo	cpotter@mail.arc.nasa.gov	Landsat 7	ETM+	Requested	Critical	Santarem					225	227	62	63	1-Jul-99
68	CD-11	Houghton	Mark Cochrane	cochrane@whrc.org	Landsat-7	ETM+	Requested	Critical	Eastern and southern Brazilian Amazonia					222	227	61	98	1-Jun-99
69	ND-10	Townsend	Greg Asner	gpa@pangea.stanford.edu	light aircraft (e.g., Otter)	Simple videography, LIDAR, spectrometry package	Requested	Critical	Tapajos region (FLONA and eastern ranches)									1-Jun-00
70	ND-10	Townsend	Greg Asner/Michael Keller	gpa@pangea.stanford.edu	light aircraft with DGPS	simple videography, LIDAR package	Requested	Important	Cauaxi	-4.5	-3	-49	-47.5					1-Jun-99
71	LC-05	Laurence	Compton Tucker	compton@kratmos.gsfc.nasa.gov	NOAA	AVHRR	Requested	Critical	Amazon Basin and adjacent areas	-55	10	-80	-25					1-Jan-99
72	LC-04	Foley	John Foley	jfoley@facstaff.wisc.edu	NOAA	AVHRR	Requested	Important	Amazon Basin and Tocantins Basin									1-Jan-81
73	ND-10	Townsend	Greg Asner	gpa@pangea.stanford.edu	NOAA TIROS	AVHRR	Requested	Critical	Amazon Basin									1-Jan-81
74	LC-05	Laurence	Compton Tucker	compton@kratmos.gsfc.nasa.gov	SeaStar	SeaWiFS	Requested	Critical	Amazon Basin and adjacent areas	-55	10	-80	-25					1-Jan-99
75	LC-10	Skole	walter chomentowski	whc@bsrsi.msu.edu	SPOT	HRV,PAN	Requested	Desirable	Amazon Basin	-20	5	-80	-40					1-Jun-86
76	LC-08	Moore	Xiangming Xiao	xiangming.xiao@unh.edu	SPOT 4	vegetation	Requested	Critical	Amazon Basin - Brazilian part	-15	15	-85	-30					1-Apr-98
77	ND-10	Townsend	Greg Asner/Michael Keller	gpa@pangea.stanford.edu	Terra	ASTER	Requested	Critical	Cauaxi	-4.5	-3	-49	-47.5					1-Oct-99
78	LC-08	Moore	Xiangming Xiao	xiangming.xiao@unh.edu	Terra	ASTER	Requested	Desirable	LBA-ECOLOGY tower sites									
79	ND-10	Townsend	Greg Asner	gpa@pangea.stanford.edu	Terra	ASTER	Requested	Critical	Tapajos region including FLONA-Tapajos and eastern ranches									1-Oct-99
80	ND-10	Townsend	Greg Asner	gpa@pangea.stanford.edu	Terra	MISR	Requested	Critical	Amazon Basin; and Tapajos region									1-Oct-99
81	ND-10	Townsend	Greg Asner/Michael Keller	gpa@pangea.stanford.edu	Terra	MISR (local mode)	Requested	Critical	Cauaxi	-4.5	-3	-49	-47.5					1-Oct-99
82	ND-10	Townsend	Greg Asner	gpa@pangea.stanford.edu	Terra	MODIS	Requested	Critical	Amazon Basin									1-Jan-00
83	TG-05	Potter	Chris Potter/Matt Bobo	cpotter@mail.arc.nasa.gov	Terra	MODIS	Requested	Critical	Amazon Basin	-34.06	6.04	-80.04	-34					1-Jan-00
84	LC-04	Foley	Jon Foley	jfoley@facstaff.wisc.edu	Terra	MODIS	Requested	Desirable	Amazon Basin and Tocantins Basin									1-Jan-00
85	TG-02	Guenther	Paulo Artaxo	artaxo@if.usp.br	Terra	MODIS, MOPITT	Requested	Critical	Amazon Basin									1-Jan-00
86	ND-10	Townsend	Greg Asner	gpa@pangea.stanford.edu	VCL	VCL	Requested	Important	Tapajos region including FLONA-Tapajos									1-Jan-01
87	LC-04	Foley	Jon Foley	jfoley@facstaff.wisc.edu	VCL		Requested	Critical	Amazon Basin and Tocantins Basin									
88	LC-08	Moore	Dr. George Hurtt	george.hurtt@unh.edu	VCL		Requested	Important	Northern South America	-15	15	-85	-30					
89	CD-07	Smith	John M. Norman	norman@calshp.cals.wisc.edu	None	None												
90	ND-08	McNabb	Ken McNabb	mcnabb@forestry.auburn.edu	None	None												
91	SCC		John Gash	John.H.C.Gash@ioh.ac.uk	None	None												
92	TG-06	Tans	Pieter Tans	pieter@netsrv1.cmdl.noaa.gov	None	None												

	Team ID	End date	Repetition rate	Process-ing level	Bands	Cloud cover	Pro-jection	Flight altitude	Pro-jection datum	GCP number	GCP for Landsat/TM	GCP for JERS SAR	GCP accu-racy in m	GPS base station availability	Ground valid. plans	Date posted	Comments
60	ND-01	2-Aug-98		0		0				none	Unknown	Unknown	unknown	Unknown	No	20-Apr-99	List of requested scenes available, max cloud cover acceptable: 25%
61	ND-10	31-Dec-01		0	all bands	4				30	Yes	Unknown	< 12	Unknown	Yes	6-Apr-99	I have carefully checked all acquisitions of Tapajos region in the Landsat 4-5 era (EDC, INPE, Pathfinder). There are very very few cloud-free scenes, but many useful scenes with cloud cover <= 60%.
62	ND-10	31-Dec-01		0	all bands	5				30	Yes	Unknown	< 12	Unknown	Yes	6-Apr-99	I have checked all databases (EDC, INPE, Pathfinder) for fractional cloud cover of TM scenes since 1984. There are very very few, but many with cloud cover <= 60%, which will be extremely useful for our efforts.
63	ND-10	31-Dec-01		0	all bands	3				40	Yes	Unknown	< 12	Unknown	Yes	6-Apr-99	One scene per year, if possible. Minimum: one scene prior to 1990, one scene in 1999-2000
64	LC-05	27-Aug-98	365	0		0				30	Yes	Unknown	20	Unknown	Yes	1-Apr-99	This is for the Gascon/Laurence (Smithsonian Inst.) group. For TM images, here are the 1st Priority (mm-dd-yy): TM 231-62: 8-27-98 6-21-97 8-21-96 8-03-95 or 10-06-95 (least cloudy) 10-19-94 (bands 1,2) 93 92 8-29-87 7-06-85 9-21-84.
65	LC-08			0		0				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	
66	TG-05	1-Sep-99		1b	all	0			south american provisional 1969	15	Yes	Yes	100,000 scale	Unknown	Yes	31-Mar-99	Interested in dry-season Landsat-5 data for the same area in 1995 or 1996. We are interested in 8 scenes covering the majority of the area undergoing active land-use change in Rondonia.
67	TG-05	1-Sep-99		1b	all	0			south american provisional 1969	0	Unknown	Unknown		Unknown	Yes	31-Mar-99	Interested in dry-season Landsat-5 data for the same area in 1995 or 1996. We are interested in 6 scenes covering the majority of the area undergoing active land-use change in Para. Interested in wet and dry season JERS data.
68	CD-11	1-Jun-02		1b	6-Jan	0				none	Unknown	Unknown	unknown	Unknown	Yes	19-May-99	Note: the proposal is pending (Houghton and Cochrane). The exact locations of most of the imagery is as yet undetermined but will reside largely along the so-called Arc of Deforestation along the eastern and southern edges of the Brazilian Amazon.
69	ND-10	30-Nov-01		0		0		0.5-1 km		30 and many planned	Unknown	Unknown	< 12	Unknown	Yes	6-Apr-99	A light aircraft package that can be easily flown on sunny days is critically needed. At a minimum, the package should include a digital video system, real-time DPGS, and a basic LIDAR system.
70	ND-10	31-Dec-01		0		0		0.5-1.0 km		40	Yes	Unknown	< 12	Unknown	Yes	6-Apr-99	Single annual overflight with light aircraft requested
71	LC-05	1-Jan-02	1	0	all	0	equal area			none	Yes	Unknown	unknown	Unknown	Yes	30-Mar-99	There will be a need for 1-km AVHRR and Seawifs time series data to enable the scaling of localized measurements. These data will also facilitate the use of Modis data, by providing a historical record back in time.
72	LC-04	31-Dec-97		2		0				none	Unknown	Unknown	unknown	Unknown	No	8-Jun-99	We are seeking for the most current NDVI data set developed using the Minimum Fine Scale Variance method.
73	ND-10	31-Dec-01		2	all optical and thermal channels	0				none	Unknown	Unknown	unknown	Unknown	No	6-Apr-99	A well-calibrated, atmospherically correction AVHRR 1 km product (NDVI and channel data)is needed to develop an historical time series of Amazon forest phenology, to be linked to MODIS effort.
74	LC-05	1-Jan-02	1	0	all	0	equal area			none	Yes	Unknown	unknown	Unknown	Yes	30-Mar-99	There will be a need for 1-km AVHRR and Seawifs time series data to enable the scaling of localized measurements. These data will also facilitate the use of Modis data, by providing a historical record back in time.
75	LC-10	1-Oct-99		1a		0	UTM		WGS84	100	Yes	Unknown	50	No	Yes	25-May-99	
76	LC-08	31-Mar-00	10-day composite	2	S10-total product, 4 bands + NDVI	0				none	Unknown	Unknown	unknown	Unknown	No	6-Apr-99	We keep using S10-total composite data of VEGETATION until MODIS data are available.
77	ND-10	31-Dec-01		1b	all bands	0				40	Yes	Unknown	< 12	Unknown	Yes	6-Apr-99	ASTER data requested twice per dry season and from two view zenith angles (across track positions)
78	LC-08			0		0				none	Unknown	Unknown	unknown	Unknown	No	6-Apr-99	We hope to have ASTER data at least once for each of the LBA-Ecology tower sites.
79	ND-10	31-Dec-01		0	all shortwave and thermal bands; two view angles if possible	1				30	Unknown	Unknown	< 12	Unknown	No	6-Apr-99	ASTER data are needed once per year for the Tapajos site. Given ASTER's 60km swath width, this will require mosaiking the images for the region each year, thus the effective data acquisition is roughly 9 images per year to cover entire Tapajos region.
80	ND-10	31-Dec-02		0	all channels, all view angles	0				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	MISR data are needed in "global mode" for entire Amazon basin, and in "local mode" for the Santarem-Tapajos region. Global mode data are needed at 9-18 day temporal frequency; local mode (Tapajos) data are needed at monthly frequency.
81	ND-10	31-Dec-01		1b	all bands, all view angles	0				40	Unknown	Unknown	< 12	Unknown	Yes	6-Apr-99	local mode MISR needed during dry season, annually
82	ND-10	31-Dec-02		1b	all optical and thermal channels	0				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	Daily, full-channel MODIS data are critically needed for our effort. All geometric info required (e.g. view zenith angle)
83	TG-05	1-Dec-01	1	2	all	0			south american provisional 1969	0	Unknown	Unknown		Unknown	No	31-Mar-99	We would like 10 day composites generated using AVHRR Pathfinder methods. Assistance in aerosol correction requested. In addition to the level 2 data we are also requesting the original channel data.
84	LC-04			3		0				none	Unknown	Unknown	unknown	Unknown	No	7-Jun-99	We would like to use as soon as possible data sets that A. Huete proposed to develop at 1km, on a 16 day, especially NDVI, land cover/change, and NPP.
85	TG-02	1-Sep-02		1a		0				none	Unknown	Unknown	unknown	Unknown	Yes	30-Mar-99	
86	ND-10	???		0		0				none	Unknown	Unknown	unknown	Unknown	Yes	6-Apr-99	Needed for biomass/canoyp structure analysis of Tapajos region.
87	LC-04			3		0				none	Unknown	Unknown	unknown	Unknown	No	7-Jun-99	We would like to use any data set concerning the structure of the canopy.
88	LC-08			0		0				none	Unknown	Unknown	unknown	Unknown	No	14-Apr-99	At reslutions and process levels available. VCL is planned to launch in 2000 as a NASA pathfinder mission.
89	CD-07															1-Apr-99	No satellite data requested at this time that is not already available.
90	ND-08															3-May-99	No satellite data requested at this time
91	SCC															1-Apr-99	No satellite data requested at this time
92	TG-06															19-May-99	No satellite data requested at this time