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RESEARCH
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Institute for Remote Sensing Applications
VEGETATION International Users Committee
Secretariat

VEGETATION

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VEGETATION Preparatory Programme

CALL for PROPOSAL

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Programme Scientist

Approved by JP Malingreau
Chairman International Users Committee

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3. ORGANIZATION OF THE VEGETATION Preparatory Programme

The total budget for the VEGETATION Preparatory Programme is 2MECU, representing about 2% of the total cost of the VEGETATION Programme for development of the first flight model and Ground Segment. This budget will be devoted to specific studies that could be contracted directly and to investigations that will be selected through Calls for Proposals with the objectives described above.

After the selection of Proposals has been made by the IUC, the technical and scientific follow-up will be the responsibility of the Programme Scientist and the IUC, and all financial management aspects will be the responsibility of CENTRE NATIONAL D'ETUDES SPATIALES acting as the « Maître d'Oeuvre » of the VEGETATION Project.

3.1 Investigations

Investigations will be selected after this first Call for Proposal. It is planned that each investigation should preferably be separated into two phases that should be described in the proposals :

1. a prelaunch phase where data sets « similar » to those that could be provided by the actual system will be used. During this phase, investigations should address all methodological and development problems.
2. a postlaunch phase, where the conclusion of the prelaunch phase should be adapted and discussed, using actual VEGETATION data sets.

No duration is imposed on the investigations during the first phase. However, the schedule of each investigation should be adapted to provide an intermediate report on the activities and on preliminary results after about one year from the beginning.

For the second phase, final results are expected to be reported about one year after the system is declared operational.

3.2 Information exchange and reporting

To maintain a high level of communication between the Programme and the investigators and to foster exchanges within the VEGETATION user community, meetings will be organized by the IUC at several critical stages of the investigations. It is envisaged to have three to four meetings for each investigation : a kick-off meeting, after each selection is announced where each investigator team will have to present its research plan and expected results, an intermediate meeting where investigators will present their Intermediate Report and a final meeting where all the results of the two phases will be presented by the investigators and discussed.

3.3 Funding

The total funds available for the investigations is a little less than 2 MECU (from 1.6 to 1.8 MECU). In principle, the selected investigations will be funded with a maximum participation of 50% from the VEGETATION Programme where only material, data and travel costs should be considered (direct labor costs will not be considered). It is also desired that funds allotted to the selected investigations are sufficient to allow for an efficient contribution to the objectives of the retained projects. During the selection phase, the IUC reserves the right to retain much less than 50 proposals for each Call for Proposal if it is deemed necessary to increase the funding level to some selected investigations

No decision has been taken concerning the generation and provision of simulated data sets by the Programme. Therefore the proposal should separately and clearly describe and justify the cost of generating the necessary simulated data sets with the assumption that they will have to be generated as part of the investigation. For actual VEGETATION data that will be used in the post launch phase, the proposal does not have to mention costs but the actual data sets should be clearly described in terms of product nature, area to be covered, dates of acquisition, preferred format and support.

The Data Simulation Plan and Data Cost Plan which must be part of the proposal as described in Appendix A will be the basis for interaction between the Programme Scientist and investigators with respect to simulated and other data distribution.

3.4 Planning

The investigations selected after this first Call for Proposal should begin in February 1995, to continue with the postlaunch phase with a nominal launch date of October 1997.

3.5 Proposal preparation

The proposal should be prepared following the guidelines given in Appendix A. It is required that all proposals include the Investigation and Technical Plan and the Management/Cost Plan. If a prospective investigator fails to observe the requirements given in Appendix A, the IUC reserves the right to return the proposal to the proponent upon receipt without further review or evaluation.

3.6 Proposal submission

The proposals should be sent in 12 copies to the following address :

Institute for Remote Sensing Applications
VEGETATION International Users Committee
attention : Gilbert SAINT
Joint Research Center
I-21020 ISPRA (Varese) Italy

They should be received no later than October 15 1994.

3.7 Selection procedure and criteria

The selection will be led by the IUC, possibly with external expertise from specialized internationally recognized experts. The following criteria will be used:

1. the relevance of the proposed investigation to the VEGETATION Preparatory Programme specific opportunity and to its objectives.
2. the scientific and technical merit of the investigation, together with its importance within the objectives of the Programme.
3. the feasibility of accomplishing the proposed investigation in the context of the schedule presented above.
4. the acceptance and proposed contribution by the Principal Investigator and any CoInvestigator to participate to the two phases of the Programme.
5. the competence and relevant experience of the Principal Investigator.
6. the reputation and interest of the investigator's institutions.
7. the quality and completeness of the Management/Cost.

1. INTRODUCTION

On behalf of the VEGETATION Programme Steering Committee, the VEGETATION International Users Committee (IUC) announces the opportunity to conduct research and development related to the characterization of terrestrial surface parameters, to the monitoring of agriculture, forestry and pasture productions and to the study of the continental biosphere. Investigations related to this Call for Proposal must be designed to contribute to the preparation of use of data which will be provided by the VEGETATION system.

The VEGETATION Programme is developed jointly by France, the European Commission, Belgium, Italy and Sweden. It is composed of an instrument which will be flown onboard SPOT 4, scheduled for launch in October 1997, and of a ground segment that will process the instrument measurements and make standard products available to the general user community. Its characteristics were tailored to monitor land surface parameters with a frequency of about once a day on a global basis and a medium resolution of about 1km. The VEGETATION system will complement the high resolution capabilities of SPOT, and provide corresponding visible to short wave infrared measurements in four spectral bands. Its original features and its situation onboard SPOT 4 will allow users to have access to :

1. robust and simple multitemporal measurements of the solar reflection domain radiative characteristics of land areas,
2. a continuous and global monitoring of the continental areas either through a centralized archiving and processing facility or using local receiving stations for local or regional studies,
3. long term data sets with accurate calibration and positionning, continuity and consistency through the renewal of the system on further satellites,
4. multiscale approaches using simultaneous measurements acquired through VEGETATION and the High Resolution instruments of the SPOT series in the same spectral bands.

Through this Call for Proposal, the VEGETATION International Users Committee solicits Proposals to prepare the user community at large, both from the Programme partner countries and from other countries or international entities, to the integration of VEGETATION data into its projects. Selection of the Proposals will be performed by the International Users Committee on the basis of their relevance to the objectives of the system and of their quality, both for scientific purposes and for operational applications.

The following domains of investigation have been defined as essential to the development and the promotion of the system itself:

- support for development or improvement of applications, primarily for the sectorial policy of the European Union (for agriculture, forestry, environment...)
- R&D on the use of remote sensing data (problems associated with scaling, integration of high frequency and high resolution data, multitemporal analysis or modeling, spectral studies —mainly in the short wave infrared).
- development leading to an enhancement of the definition of the proposed products or to algorithms to be implemented in the Ground Processing Segment.

The IUC plans to select at most about 100 projects : these projects will be selected from Proposals made in response to two Calls for Proposal, the present one and a second one that will be issued around the end of 1995. The selected projects will preferably be conducted in two phases : a pre-launch phase, using only simulated data sets and a post launch phase where actual data acquired through the validated VEGETATION system will be made available for final conclusions.

The results of the investigations should be made available to the VEGETATION Programme and to the entire user community through publications, documentation, workshops or symposia.

2. INVESTIGATION GOALS AND OBJECTIVES

The basic objectives of the VEGETATION Preparatory Programme are :

i. to foster development of methodologies for the use of medium spatial resolution and high frequency remote sensing data for vegetation studies : the availability of similar data sets for about ten years (namely from NOAA-AVHRR) has lead to a rapid increase in research activities and applications related to regional and global analyses of the land areas, even when the systems which provided these data sets were not designed to facilitate measurements on vegetation canopies. As VEGETATION will provide products which are specifically tailored to improve quality of such measurements, the user community must develop an ability to extract the most adequate information from these improved kinds of data sets.

ii. to prepare the integration of VEGETATION data sets into existing projects or projects still under development which are routinely using or will use similar data sets before 1997: the specific characteristics of the system were designed to provide products which are adapted to identified projects or programmes, both through their technical features (spectral bands, radiometric and geometric accuracies...) and through the operationality of the entire system (delivery time and quality control for products, long term commitment...). As the design was entirely based on generally known methodologies, it is expected that the VEGETATION data sets will be included almost directly into the existing projects. Improvements related to the quality and adaptation of VEGETATION data sets can also be prepared in advance to benefit from the system as soon as possible after launch.

The VEGETATION Preparatory Programme will be based both on projects which will be selected through Calls for Proposal such as this one and on studies that will be contracted by the Programme to fulfill particular points which are deemed necessary to better define the characteristics of the system. The investigations proposed in response to this Call for Proposal should contribute to the above goals of the VEGETATION Preparatory Programme. Specific fields have been defined by the IUC as priorities for these investigations. They correspond to priorities that should be taken into account in the proposals in order for them to fit better the general objectives. These priorities are based on the most important aspects that should be developed as major sectors where VEGETATION data will be used, taking as much benefit as possible from its specific characteristics and from the capability to associate simultaneous high spatial resolution measurements from the SPOT series.

Propositions to the Call for Proposal should then focus on the following fields :

1. support for development or improvement of applications or scientific projects using VEGETATION type data
    - to better evaluate the impact of the use of VEGETATION on the quality and operationality of the projects
    - and to prepare the integration of VEGETATION products into the systems and procedures which contribute to the objectives of these projects.

   A high priority will be given to projects which are related to the sectorial policies of the European Union, and to activities, both for application and for science, which are supported either by the European Union or by the partners of the programs. For this category of investigation, proposals should concentrate on the impacts of specific VEGETATION characteristics such as : « almost real time » access to any region, multitemporal measurements, capability to mix VEGETATION and high spatial resolution data (both from simultaneous SPOT acquisitions and other sensor systems), the short wave infrared spectral band, the « experimental » blue band for possible atmospheric effects characterization.

2. development of methodologies for the use of remote sensing data. This will be considered only when the specific characteristics of VEGETATION offer new capabilities or imply research and development activities to improve the quality of informations which can be extracted from the VEGETATION products. The topics which are priorities for selection are the following :

   - multiscale analysis using simultaneous or asynchronous high spatial resolution data and possibly ground sampling techniques. Proposals could emphasize on the association and complementarity of VEGETATION (for frequent acquisitions) and of high spatial resolution systems (for less frequent acquisitions but giving access to spatial heterogeneity for subpixel analysis and/or to information on other biophysical parameters of vegetation canopies),
   - multitemporal analysis related to the dynamics of the surface processes. Proposals could be built on the use of the VEGETATION consistent data sets (calibration, geometric registration accuracies) on different time scales, from seasonal to multi year studies, to address problems related to vegetation or ecosystems functioning and to the interaction between biosphere and climate,
   - physical and biophysical parameters extraction. For this topic, proposals should show benefits due to the spatial and temporal sampling rates which are provided by the VEGETATION products, including all spectral measurements and especially the short wave infrared and blue bands.

3. definition of improved products that could be generated by the VEGETATION Ground segment making full use of the specific characteristics of the system. The capability to improve the standard VEGETATION products is a specification for the entire system and will be possible with a frequency of every 18 months to two years. While the first set of product has now been defined and should be kept for development efficiency, minor modifications might be considered and a definition of evolution for the first update is expected from some investigations. Proposals which focus on that type of investigations should conform to the basic principle which was applied for the first product definition : namely that new products or methods should be widely accepted by the users community at large (through usual exchanges, publication in scientific journals...) and be applicable for products to be delivered to the entire user community and not only for specific applications or geographical areas.

For information, as an indication of the weight that will be assigned to each of the above priorities, the following distribution was defined by IUC as being a good sharing of the interest of the program : about 50% of the effort should deal with support to projects (field 1), 30% on methodological development (field 2) and 20% on definition of improved products (field 3).

3. DESCRIPTION OF THE VEGETATION SYSTEM

(This section is a summary of the specifications which are given in the two annexes on Mission specifications and Products definition)

The overall objectives of the VEGETATION system are to provide accurate measurements of basic characteristics of vegetation canopies on an operational basis,

- either for scientific studies involving both regional and global scales experiments over long time periods (for example development of models of the biosphere dynamics interacting with climate models),
- or for systems designed to monitor important vegetation resources, like crops, pastures and forests.

The VEGETATION system, consisting of a satellite-borne sensor and of its associated ground segment, will provide long term basic measurements adapted to biosphere studies. Opportunities for scale integration are provided by the combination with the main SPOT instruments (HRVIR High Resolution Visible and shortwave InfraRed) which allow high spatial resolution for detailed modelling activities or multilevel sampling procedures. Availability of data to different types of users is facilitated through the centralisation of reception and archiving global data sets. The launch date (nominally October 1997) and duration of the system (5 years of estimated life time for a first model and continuation on future SPOT satellites) are adapted to a systematic and extensive long term monitoring of the biosphere.

Clearly this system will benefit from detailed studies based on other systems that are dedicated to specific studies of the characteristics of remote sensing measurements or to their relationships with surface or processes' parameters. It must be envisaged that the evolution of the mission specifications will have to take into account results of such studies to provide improved characterisation of the biosphere state and dynamics.

3.1 Mission objectives

Three types of mission were identified for the system, taking into account the need for measurements of surface characteristics and the existence of other systems which are already or will provide other measurements which to infer various parameters related to biosphere processes :

• Surface parameters mapping : this is the basic requirement, especially for climate and meteorological studies where boundary conditions have to be prescribed as in the case of General Circulation Models or forecasting models. Factors such as albedo, surface roughness, resistances to heat exchanges —sensible and latent— are important variables for these models and they can be either determined directly from the measurements or inferred from identification of land cover. The seasonal and long-term variations of such variables are related to vegetation dynamics. The capability to identify, through these variations, physical characteristics of land cover is a key to accurate prescription of these variables. Scales addressed in GCM or forecasting models (typically about 100 km) require that land cover and its variability must be determined with a sampling of about 8 to 10km: the basic spatial resolution needed for identification of land cover and its variability is 1 km.

• Agricultural, pastoral and forest production : since the beginning of the land surface satellite remote sensing era (1972), important projects (for example LACIE, AGRISTARS for USDA, MARS for CEC, TREES for JRC/ESA...) have been set up to develop methodologies and strategies to use remote sensing data either for mapping of land use in anthropogenized or natural ecosystems or for estimation of production potential. Their specific objective was to determine the evolution of productions. This objective had to be adapted to the management of crop production for agricultural exporting countries, to the monitoring of pastoral resources and their dependence from meteorological evolution, to the evaluation of possible global impacts of deforestation and more generally to the need for information related to political or social orientations and decisions.

• Terrestrial biosphere monitoring and modelisation : the contribution of the continental biosphere to the biogeochemical cycles (exchanges of carbon and other trace gases) and to water and energy exchanges is one of the objectives of the development of global models. Interaction with human activities is also one of the main points to be studied, because the effect of human pressure on the biosphere might be one of the means by which man is acting on climate in the long term. Biosphere processes and land cover characterisation are the basis for quantification : estimations of land cover variables as well as the dynamics of these variables have to be made in order to obtain a good understanding of these processes upon which models may be built. Predictions of impact of climate change on the biosphere and of interactions of the biosphere with the climate — either due to natural factors or to human pressure— can only be inferred from quantification and formalisation of the mechanisms by which vegetation cover and ecosystems are functioning. Multilevel series of models have to be developed and linked, ranging from ground studies, local parameterisation and exchange models to regional or global dynamics and interaction models. Remote sensing of the vegetation as shown above offers a unique tool for these developments, providing the specification of the systems be adapted to each particular need.

3.2 System characteristics

Radiometry

Spectral bands		Wavelength	Surface refl. range
Operational :	RED	0.61 - 0.68 μm	0.0 - 0.5
	NIR	0.78-0.89 μm	0.0 - 0.7
	SWIR	1.58-1.75 μm	0.0 - 0.6
Experimental :	BLUE	0.43-0.47 μm	0.0 - 0.5

Radiometric resolution ($NE\Delta\rho$)
RED : 0.001% up to reflectance of 0.10%, linear increase up to 0.003% for reflectance of 0.5%
NIR, SWIR : 0.003% for the entire range
BLUE : 0.003% for the entire range

Intra-image consistency : within an entire image, corresponding to a $NE\Delta\rho$ of 0.005 for any reflectance value

Calibration accuracy :
interband and multitemporal : better than 3%
absolute : better than 5% .

Geometry

Spatial resolution : in both directions 1.15 km at nadir, minimum variations for off-nadir observations

Field of view : maximum off-nadir observation angle of about 50.5° (~2200 km swath width)

Geometric accuracies :
local distortion : less than 0.3 pixel,
multispectral registration : 0.1 km desired
0.3 km specified
collocation with HRVIR : 0.3 km for the simultaneous acquisitions

multitemporal registration :	0.3 km desired, 0.5 km specified
location accuracy :	better than 500m desired, 1000m specified

Spatial coverage : about 90% of the equatorial areas are imaged each day, the remaining 10 % being imaged the next day. For latitudes higher than 35° (North and South), all regions are acquired at least once a day

Operation specifications

Equator crossing time (descending node) : 10:30 local solar time

Image transmission : All spectral bands at full spatial resolution acquired on terrestrial areas will be stored onboard in a solid state memory, allowing the use of only one receiving station to which data will be transmitted in X band. All the spectral bands will also be transmitted in L band, for possible local receiving stations.

3.3 Products characteristics

The standard products have now been defined by the International Users' Committee. They are adapted to the particular missions described above and coherent as much as possible with the needs of existing projects. Two general categories of users could be identified :

- research teams which are developping methodologies for the use of VEGETATION data or scientific biosphere studies : they generally have a study site (about 500 x 500 km2) and need long time series (one year of daily or weekly data).
- projects which are based on the use of both VEGETATION and other data sets, for which the data delivery has to be fully operational and for long periods, for comparison or historical studies (one continent every day). Typically, these projects are : MARS, TREES, IGBP...

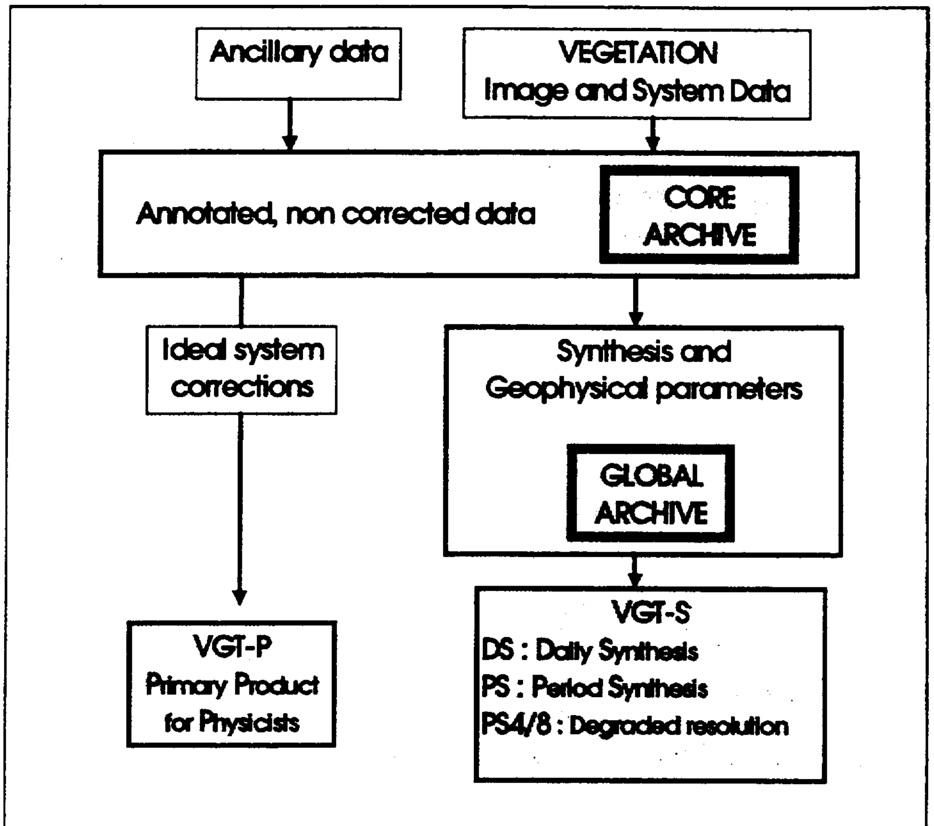
The overall organisation of the different levels as well as the general characteristics of the products are now defined, as shown in the attached figure. To illustrate the special characteristics of the instrument, high priority was given to design products that would allow direct multitemporal registration as well as simple superposition with simultaneously acquired high resolution data.

VGT-P products are adapted for the first type of users for which physical quality of data is important. They correspond to data which would have been acquired by an ideal instrument : they are corrected for system errors (misregistration of the different channels, calibration of all the detectors along the line-array detectors for each spectral bands) and resampled to geographic projections for multitemporal analysis as well as for comparison with high resolution data. The accuracies given above apply to this data level. Annotations giving full information on applied corrections (calibration information, geometric parameters taking into account attitude and position on the orbit), or for further non-system corrections ("standard" atmosphere parameters) are attached to the data sets.

VGT-S products are most probably the data sets which will be frequently used operationally : they correspond to VGT-P data to which corrections have been applied using the annotations and for which some syntheses are provided :

• a daily synthesis using all available measurements on one day for a specific location,

• a 10-day synthesis, based on the selection of the "best" measurement of the entire period. The selection could be based on the maximum NDVI value, as it is commonly accepted today, even if many problems associated to that selection are identified.



General structure of the VEGETATION Products

To adapt to the evolution of users needs as well as to the validation of new algorithms, a procedure to regularly update the processing system is requested : it should provide capabilities to include new methods for data correction, synthesis... as soon as they are commonly accepted by the user community.

Support to users will be provided to facilitate the use of VEGETATION data : a catalogue with browsing capability on the data quality (cloudiness) will be accessible through telecommunications lines and usual networks. Validated software templates for the common operations for data handling and standard correction will be made widely available.

3.4 Programme organization

To develop the entire system and prepare its exploitation, the partners set up a structure which is composed of a Steering Committee, an International Users Committee and an Integrated Project Team. The role of each of the entities is the following :

The Steering Committee (SC) gives guidelines concerning the development to all the entities which are part of the Programme :

- it approves the mission specifications and any modification proposed by the International Users Committee (IUC),
- it approves the management and organisation plan submitted by the Integrated Project Team (IPT) and supervises its application, receiving reports on all aspects of the Project Management.

The Steering Committee is composed of representatives of all the partners of the Programme. The chairman of the International Users Committee and the Programme Scientist are observers to the SC.

The International Users Committee (IUC) represents and voices the interests of the international community of remote sensing data users in the VEGETATION Programme. It submits specifications and technical recommendations to the Steering Committee :

- defining the mission and products,
- providing advice to the Programme Scientist regarding modifications to the initial specifications during the development phase,
- preparing technical recommendations regarding data reception, processing, archiving and distribution,
- preparing and managing a VEGETATION Preparatory Programme to stimulate the interest of a broader users community into the capability of the system and to prepare the users to efficient integration of VEGETATION data into their projects,
- proposing orientations for the evolution of the Programme after the launch of the first instrument.

The Programme Scientist ensures coordination between the IUC and the IPT and the secretariat of the IUC. He also manages, on behalf of the IUC, the VEGETATION Preparatory Programme.

The Integrated Project Team (IPT) is in charge of the complete follow-up of the payload and ground segment development and its integration on SPOT 4, until the in-orbit acceptance.

- it drafts all major technical and management specifications in accordance with mission specifications and monitors their application,
- it manages all activities concerning contracts to national industries

The « Maitre d'Oeuvre » for the VEGETATION Project is Centre National d'Etudes Spatiales (CNES)

4. ORGANIZATION OF THE VEGETATION Preparatory Programme

The present Call for Proposal is part of the VEGETATION Preparatory Programme which is led by the VEGETATION International Users Committee under executive responsibility of the Programme Scientist. The general orientations of the VEGETATION Preparatory Programme were approved by the VEGETATION Programme Steering Committee. The total budget for the VEGETATION Preparatory Programme is 2MECU, representing about 2% of the total cost of the VEGETATION Programme for development of the first flight model and Ground Segment. This budget will be devoted to specific studies that could be contracted directly and to investigations that will be selected through Calls for Proposals with the objectives described above.

4.1 Responsibilities

While the Steering Committee will have to approve all actions related to it, the VEGETATION Preparatory Programme will be executed under responsibility of the VEGETATION Programme Scientist, with permanent participation of the IUC, especially during the phases concerning the definition of objectives of the Calls for Proposal, the selection of investigations and the evaluation of results. The objectives of the Second Call for Proposal will be defined at a later stage.

After the selection of Proposals has been made by the IUC, the technical and scientific follow-up will be the responsibility of the Programme Scientist and the IUC, and all financial management aspects will be the responsibility of CENTRE NATIONAL D'ETUDES SPATIALES acting as the « Maître d'Oeuvre » of the VEGETATION Project.

4.2 Call for Letters of Intent

The first action of the VEGETATION Preparatory Programme was a Call for Letters of Intent which was issued in March 94. Its objectives were to identify individuals or teams that would be interested to participate to the Programme, to have a survey of topics that were most frequently presented for potential investigations and to assess the need of specific simulated data sets that would have to be generated by any means.

About 180 letters were received and their analysis led to establish the priorities which are outlined in the Investigation Goals and Objectives section. The IUC envisages to select a maximum of about 100 investigations for the entire duration of the VEGETATION Preparatory Programme.

The need for simulated data sets appeared to be quite different depending upon the type of project for which an intention to submit a proposal was declared : for participation to large projects related to fields 1 & 2 of the objectives, a large majority of the letters of intent were indicating that data sets were already existing or were part of the project, thus requiring no specific action from the VEGETATION Preparatory Programme: for other participation, mainly limited in space and time and related to fields 2 and 3, small simulated data sets were expected from the VEGETATION Preparatory Programme.

As it was apparent from the letters of intent that the generation of data sets could lead to a large number of simulations that would be quite different in terms of geographical area, periods (dates and length), type of data (spectral bands, resolutions,...) no decision to generate simulated data sets was taken. Therefore, for each proposal, the need for simulated data sets will have to be presented in the Data Simulation Plan as described later in Appendix A and a decision to provide the data sets or to contribute partially or totally to their generation will be taken on a case by case basis considering the proposals themselves.

4.3 Investigations

Investigations will be selected after this first Call for Proposal. It is planned that each investigation should preferably be separated into two phases that should be described in the proposals :

1. a prelaunch phase where data sets « similar » to those that could be provided by the actual system will be used. During this phase, investigations should address all methodological and development problems. All hypotheses and issues presented as the objectives of the proposal should be addressed during this phase, based on the assumptions that data sets which are used are representative of the actual VEGETATION data or describing and taking into account differences between the data sets which are used and the actual ones. Limitations to the conclusions and the

extrapolations that could be made to assess the usefulness of VEGETATION will have to be clearly presented.

2. a postlaunch phase, after the entire system is declared operational, where no essential methodological or development problem should have to be addressed (except those related to adaptation of data formats or related actions). During this phase, the conclusion of the prelaunch phase should be adapted and discussed, using the results of application of methods and procedures defined and tested in phase 1 on actual VEGETATION data sets. The proposal should clearly present the strategy for this second phase, especially the data needs (which are not necessarily the same as for the first phase), and the objectives and methods to be used to finally assess the usefulness of VEGETATION products for the needs of the investigation.

No duration is imposed on the investigations during the first phase. However, the schedule of each investigation should be adapted to provide an intermediate report on the activities and on preliminary results after about one year from the beginning. Longer investigations should plan a second report some time before launch of the system where all the conclusions of the first phase should be presented.

For the second phase, final results are expected to be reported about one year after the system is declared operational.

4.4 Information exchange and reporting

To maintain a high level of communication between the Programme and the investigators and to foster exchanges within the VEGETATION user community, meetings will be organized by the IUC at several critical stages of the investigations. During these meetings, the investigators will be informed of the latest development of the Programme and research plans or progress reports of investigations will be presented. These meetings will also offer opportunities for exchanges among the international user community, scientific cooperation and sharing of information related to the Programme and to fields of activity related to the mission of the Programme. The investigators might also use these meetings to make their comments on the progress of the Programme, make recommendations for future evolution either of the first Ground Segment, of its first update or on the next system that will follow the first one. Some specialized workshops might be established as appropriate to address specific scientific or technical objectives. It is envisaged to have three to four meetings for each investigation :

- a kick-off meeting, after each selection is announced : during this meeting, each investigator team will have to present its research plan and expected results,
- an intermediate meeting (possibly two for investigations selected from Call for Proposal #1 that would require two years for the prelaunch phase) where investigators will present their Intermediate Report,
- a final meeting where all the results of the two phases will be presented by the investigators and discussed.

If appropriate, another meeting might take place after launch when the system is declared operational where the quality of the actual system would be presented to the investigators to prepare the beginning of the postlaunch phase.

Proceedings of the intermediate and final meetings will be published by the Programme Scientist and the IUC and be made available to the entire community. These proceedings will be edited jointly with each Principal Investigator.

Besides, all investigators will be firmly encouraged to publish their findings in the usual scientific and technical journals. They may also be invited to present their results in scientific or technical meetings organized by the partners of the Programme.

Note : travel costs of these meetings should be part of the cost plan for the proposals.

4.5 Schedule

From the analysis of the letters of intent, the principle to have two Calls for Proposals was retained, and the schedule of events is given in the following table:

Date	Call for Proposal #1	Call for Proposal #2
July 1994	First Call for Proposal issued	
October 15th 1994	Deadline for submission of proposals in response to First Call	
December 1994	Announcement of First Set of Selected Investigations	
February 1995	Beginning of First Set of Investigations - KickOff Meeting	
December 1995		Second Call for Proposal issued
April 1996	First Intermediate Report	Deadline for submission of proposals in response to Second Call
April 1996		Announcement of Second Set of Selected Investigations
June 1996	First Intermediate Meeting	Beginning of Second Set of Investigations - Kick Off Meeting
April 1997	Second Intermediate Report	Intermediate Report
June 1997	Second Intermediate Meeting	First Intermediate Meeting
January 1998	Beginning of Post Launch Phase	
November 1998	Final Report	
December 1998	Final Meeting	

Note : Dates for Intermediate and Final Reports are indicated for draft reports which will have to be submitted before they are presented in the following meeting.

The schedule for the postlaunch phase will possibly be adapted to the effective date at which the VEGETATION system will de declared operational.

4.6 Funding

As mentioned above, the total funds available for the investigations is a little less than 2 MECU (from 1.6 to 1.8 MECU). The IUC and Steering Committee have recommended a maximum of about 100 investigations retained for the two selections mentioned above. In principle, the selected investigations will be funded with a maximum participation of 50% from the VEGETATION Programme where only material, data and travel costs should be considered (direct labor costs will not be considered).

It is also desired that funds allotted to the selected investigations are sufficient to allow for an efficient contribution to the objectives of the retained projects. Proponents are recommended to establish all the links they could find necessary to group similar or related proposals and then get substantial support from the VEGETATION Preparatory Programme. During the selection phase, the IUC reserves the right to retain much less than 50 proposals for each Call for Proposal if it is deemed necessary to increase the funding level to some selected investigations.

Data Costs :

As mentioned above, no decision has been taken concerning the generation and provision of simulated data sets by the Programme. Therefore the proposal should separately and clearly describe and justify the cost of generating the necessary simulated data sets with the assumption that they will have to be generated as part of the investigation. This information should be clear so that the IUC can estimate the cost of the investigation with no data set generation if the simulated sets are generated in a centralized manner for all the investigations.

For actual VEGETATION data that will be used in the post launch phase, the proposal does not have to mention costs but the actual data sets should be clearly described in terms of product nature, area to be covered, dates of acquisition, preferred format and support.

The Data Simulation Plan and Data Cost Plan which must be part of the proposal as described in Appendix A will be the basis for interaction between the Programme Scientist and investigators with respect to simulated and other data distribution.

5. REQUIREMENTS AND CONSTRAINTS

This Call for Proposal is open to any individual or team, with no limitation concerning nationality, type of organisation, structure and components of the proposing team.

5.1 Number and organization of investigations

As mentioned above, the IUC expects to select a maximum number of about 100 investigations, shared between the two Calls for Proposals.

It must be noted that the IUC may desire to select only part of a proposed investigation or to propose to several investigators that they merge their proposed investigations into a single one, when two or more proposals address similar or complementary topics and when a joint investigation is felt more efficient. Furthermore, the IUC has the option to propose a phased implementation for any investigation; in that case, the development could be discontinued at the completion of the prelaunch phase.

Each proposal must designate a Principal Investigator who will be responsible for the definition, planning and implementation of the efforts, including the quality of the scientific and technical investigation, dissemination of results and all developments and timely delivery of required reports.

Investigations that require more than one investigator may include CoInvestigators. However, the Principal Investigator will be responsible for the work performed by its CoInvestigators. Each CoInvestigator must have clearly defined responsibilities in the definition and execution of the proposed investigation. These responsibilities should be explicitly described and justified in the proposal.

The Principal Investigator will be the only point of contact for all contractual matters related to the investigation.

5.2 Investigation and technical plan, management and cost plan

The investigations should preferably be planned to be conducted in two phases and the investigations selected after this first Call for Proposal should begin in February 1995, to continue with the postlaunch phase with a nominal launch date of October 1997. All planning should be based on these dates and the investigation and technical plan, management and cost plan as defined in Appendix A should address the activities of the two phases, according to the objectives of each phase as described above.

5.3 Proposal preparation

The proposal should be prepared following the guidelines given in Appendix A. It is required that all proposals include the Investigation and Technical Plan and the Management/Cost Plan.

As a large number of proposals are expected to be submitted, in order to insure fairness to all applicants and keep within the planned schedule, the organisation and length restrictions given in Appendix A will be strictly enforced. If a prospective investigator fails to observe the requirements given in Appendix A, the IUC reserves the right to return the proposal to the proponent upon receipt without further review or evaluation.

5.4 Proposal submission

The proposals should be sent in 12 copies to the following address :

Institute for Remote Sensing Applications
VEGETATION International Users Committee
attention : Gilbert SAINT
Joint Research Center
I-21020 ISPRA (Varese) Italy

They should be received no later than October 15 1994.

5.5 Selection procedure and criteria

The selection will be led by the IUC, possibly with external expertise from specialized internationally recognized experts. The recommendation for selection and support of investigations will be transmitted to the Steering Committee for approval.

During the selection phase, reviewers will evaluate the scientific and technical merits of each proposed investigation in terms of its strengths and weaknesses. The scientific and technical merits will be evaluated prior to any cost aspects and will be considered as a first basis for possible final selection. Costs aspects will then be analyzed taking into consideration the availability of funds for the entire set of investigations and the balance between the different fields.

The scientific and technical evaluation process will identify the best scientific and technical proposals to meet the goals of the VEGETATION Preparatory Programme as defined above in section 2, and to ensure that a balanced set of results is obtained and made available to the user community. It should lead to recommendations for the support of the selected investigations by the Programme. The following criteria will be used:

1. the relevance of the proposed investigation to the VEGETATION Preparatory Programme specific opportunity and to its objectives,
2. the scientific and technical merit of the investigation, together with its importance within the objectives of the Programme,
3. the feasibility of accomplishing the proposed investigation in the context of the schedule presented above,
4. the acceptance and proposed contribution by the Principal Investigator and any CoInvestigator to participate to the two phases of the Programme,
5. the competence and relevant experience of the Principal Investigator and any CoInvestigators and collaborators as an indication of their ability to carry the investigation to a successful conclusion, including communication of results,

6. the reputation and interest of the investigator's institution, as measured by its willingness to provide necessary support to complement support by the VEGETATION Preparatory Programme to ensure that the investigation can be completed satisfactorily.
7. the quality and completeness of the Management/Cost Plan ensuring realistic planning for achievement of the different phases within the funding proposal.

5.6 Reports and publication of results

Investigators selected through this Call for Proposal will be required to provide reports and to participate in the intermediate and final meetings. The reports will be the basis of the presentations in the meetings. For each of these reports, a draft must be submitted to the Programme before the meeting for publication. The IUC reserves the right to discuss assumptions and results.

The final reports or results will be made available as soon as possible to the general user community through publication in related journals or presentation at conferences.

Any publication on results related to the selected investigations should mention that they were obtained by an investigation selected by the VEGETATION Preparatory Programme. In the event that such publication is copyrighted, the partners of the Programme shall have a royalty free right under the copyright to reproduce and use such copyrighted work for their own purposes.

Investigators selected as a result of this Call for Proposal are expected to make available to the partners of the Programme all techniques developed, methods of analysis and results in the course of their investigations in accordance with the limitations mentioned in Appendix B.

APPENDIX A : INSTRUCTIONS FOR PROPOSAL PREPARATION

A.1 Introduction

Proposals submitted to the VEGETATION Preparatory Programme should adhere to the following guidelines for format and content. While strict adherence to these guidelines is not absolutely necessary, a uniform format is desired to aid the IUC to review and evaluate strengths and weaknesses of all the proposals, with maximum fairness to all applicants. Proposals must provide information related to all items described in this section and as otherwise specified in this Call for Proposal.

All proposals should contain an Investigation and Technical Plan describing the technical aspects of the investigation and a Management/Cost Plan describing how the investigation will be implemented. The Investigation and Technical Plan should include a Data Simulation Plan where particular aspects related to data simulation techniques should be clearly presented. The Management/Cost Plan should include a Data Cost Plan where particular aspects related to data simulation costs should be clearly presented.

Proposals should be typed single space, with text in font size no smaller than 10 points. The applicants should conform to the page limits given in the following sections. Appendices and annexes can be added when they are felt necessary. However, the proposal text within the page limit should be self consistent and appendices or annexes should not include any essential information for the evaluation of the proposal. Every effort should be made to keep the proposal as brief as possible, while still providing all required information.

All proposals must be submitted in English, with abstracts in English and French. A French version of the proposal may be appended. They must be submitted in 12 copies, each copy including all the appendices and annexes even when they are not required in the proposal format.

A.2 Proposal format and content

All proposals should be composed of the following parts :

- a cover letter,
- a title page with identifying information (1 page),
- abstract pages (2 pages),
- a table of contents,
- an investigation and technical plan (up to 20 pages),
- a management and cost plan (up to 10 pages),
- a biographical part,
- a bibliography

and possible appendices.

A.2.1 Cover letter

A letter or cover page should be forwarded with the proposal. It should be signed by the Principal Investigator and an official of the Principal Investigator's organisation who is authorized to commit the organization to the contents and implementation of the proposal. In case of a CoInvestigator, it is the responsibility of the Principal Investigator to ensure the commitments of CoInvestigator's organizations. This cover letter should include the name and address of the organization's authorizing official.

A.2.2 Title page (one page)

A title page should include all necessary information to identify the proposal :

- Proposal Title (brief and descriptive),
- Type of Proposal
- Principal Investigator name, address, telephone and fax numbers, email address,
- Names of all CoInvestigators, with their organizations, addresses, telephone and fax numbers, email addresses,
- Total proposed budget of the proposal, showing year by year and total requests,
- Costs for simulated data generation, showing year by year and total requests,
- References to parallel or related proposals to the VEGETATION Preparatory Programme.

It is required that proponents follow the title page format given in appendix C.

A.2.3 Abstract pages (2 pages)

It should contain keywords that could be used to index the proposal and one page abstracts summarizing the objectives, scientific and technical approach and anticipated results. English and French abstracts are required (one page each). The abstracts should contain a simple, concise overview of the investigation, its conduct, the expected results and their relevance to the VEGETATION Preparatory Programme goals and objectives. It is very important that these abstracts be specific and accurately represent the proposed research.

A.2.4 Table of Contents

The table of contents should clearly indicate page numbers of all the major sections of the proposal, including the Data Simulation Plan, the Data Cost Plan and the Cost Plan.

A.2.5 Investigation and Technical Plan (up to 20 pages)

The Investigation and Technical Plan should contain a detailed statement of the investigation to be undertaken and should describe objectives, scientific and technical justification, technical approaches and expected significance of the work.

Experimental objectives :

The proposal should identify and detail its contribution to each of its fields of relevance among the fields listed in section 2.

A brief description of the scientific and technical objectives and their relationship to past efforts and the current state of the art should be provided. The scientific rationale for the proposed investigation should be clearly established through reference to existing scientific and technical literature and other publications. The proposed investigation should be defined in relation to the current state of the art and to the specific objectives of the VEGETATION mission. Proponents are encouraged to define explicit hypotheses that will be tested and evaluated by the proposed investigation.

Approach:

The concept of the investigation should be clearly stated and the methods to be employed in data analysis and interpretation results should be presented. The data analysis should be clearly related to one of the following categories :

1. application of proven techniques for analyzing multispectral, multitemporal or multiscale data to a new problem or a new geographical area including VEGETATION data,
2. extrapolation of conventional methods that are already used on data sets which are similar to VEGETATION data sets and possible other sensors data sets,
3. development of new procedures or techniques for handling and analysis of multispectral, multitemporal or multiscale data acquired by VEGETATION and possible sensors,
4. development for procedures or techniques specifically adapted to the new features of VEGETATION.

Experimental and Work Plan

The general plan of research should be outlined, experimental methods and procedures to be undertaken should be described in sufficient detail for the IUC to adequately assess their contribution to the scientific and technical approach.

The overall methodology and sequence of key points of the investigation should be presented in detail, including description of plans for each of the two phases (prelaunch and post launch) and the relationships between these two.

Data Simulation Plan :

The Investigation and Technical Plan must include a special section on data sets generation for the prelaunch phase : the data sets that will be used must be described and their representativity as VEGETATION simulated data sets should be justified, taking into account the specific objectives of the proposal. Any limitation to the interpretation of these data sets and to the extrapolation to the interpretation of actual VEGETATION data should be clearly identified and related to the structure of experimental plans for the prelaunch and postlaunch phases.

Specific requirements that would have to be taken into account should the simulated data sets be generated under the responsibility of the IUC, must be clearly stated in that section.

VEGETATION Data Plan

For actual VEGETATION data that will be used in the post launch phase, the proposal should clearly describe the data sets in terms of product nature, area to be covered, dates of acquisition, preferred format and support.

Anticipated results :

As far as possible, the expected outcome of the investigation should be presented, with specific formulation for each of the two phases. The significance and implication of these results to related projects which are important for the future use of the VEGETATION Programme should be discussed.

Significance of the investigation :

The significance of the proposed investigation should be defined in terms of its relationships with earlier studies and of the implication of its anticipated results. The proposal should attempt to characterize the degree of innovation associated with the objectives or approach and the impact of using VEGETATION data on its anticipated results.

A.2.6 Management and Cost Plan (up to 10 pages)

Management Plan :

The Management Plan sets forth the investigator's approach for efficiently managing the work, recognizing essential management functions and effectively integrating these functions in the overall execution of the investigation. The Management Plan should give insight into the organization proposed for the work, including the internal operations and lines of authority with delegations, together with internal operations and relationships with the IUC or Programme Scientist, subcontractors or associated investigators. Likewise the Management Plan should reflect various schedules necessary for the logical and timely pursuit of the work, accompanied by a description of the Principal Investigator's work plan and the responsibilities of the CoInvestigators if any. Roles and responsibilities of all investigators and collaborators must be adequately described.

All major facilities and equipment essential to the proposed investigation should be indicated, including those of the investigator's contractors. Existing equipment should be explicitly differentiated from facilities that will be developed to implement the investigation. Procurement schedules and lead time for the acquisition and installation of new equipment and/or facilities should also be indicated. The development of new equipment and facilities will be strictly limited to the support required to fulfill the VEGETATION Preparatory Programme objectives.

Cost Plan

The Cost Plan should summarize the total investigation cost by major categories of cost as well as by function. It must be broken down into the following categories that apply : supplies and materials, equipments, computer time, services, publication costs, communications, travel and other cost items to be detailed. While salaries and wages will not be considered during the selection to determine the level of funding by the VEGETATION Preparatory Programme, associated costs could be indicated briefly as they give indications on the willingness of the proposing organisations to contribute to the Programme.

Each category should be detailed and explained. Equipment purchases should specify the type of equipment, number of units and unit cost. Travel expenses should give the estimated number of trips, destinations, duration, purpose, number and role of travellers, anticipated dates.

The Cost Plan should mention the cost of attending the intermediate(s) and final meetings, with the assumption that they will take place in Europe.

The Cost Plan should list other sources of funding and their scheduling for any aspect of the investigation.

A particular section of the Cost Plan should be the Data Cost Plan where all the costs related to the generation of simulated data sets justified in the Investigation and Technical Plan should be detailed clearly enough for the IUC to evaluate the cost of the investigation under each of the two following assumptions :

- the simulated data sets are generated under responsibility of the Principal Investigator as part of the investigation
- or the simulated data sets are generated under the responsibility of the IUC and provided for reproduction costs to the Principal Investigator.

The Cost Plan should present separate schedules for each year and for the above categories. Any detail giving insight to the breakdown of costs will be appreciated, especially to allocate expenses to the Principal Investigator's and CoInvestigator's activities, ancillary data sets to be acquired, data analysis and processing, possible field studies...

A.2.7 Biographies

Brief resumes (one page maximum for each) of all named investigators and collaborators should be enclosed. They should include a list of scientific or technical contributions made in the last six years and a list of the five most significant publications.

A.2.8 Bibliography

A bibliography related to the investigation should be attached, limited to the most significant publications which are relevant to the proposed investigation.

APPENDIX B : PROPOSAL EVALUATION AND SELECTION

B.1 Tentative selection, phased development, partial selection, selection with discussion

By submitting a proposal, the investigator and his organisation agrees that the IUC has the option to make a tentative selection pending a successful feasibility or definition study of the proposed investigation, especially related to limitations in data availability (either simulated or actual data), and, in addition, upon confirmation of the availability of adequate support of other sources of funding indicated in the Cost Plan. Furthermore, the IUC has the option to recommend a contract in phases for implementation of a proposed investigation and to discontinue the development of an investigation effort at the completion of any phase.

The investigator should also understand that the IUC may desire to select only a portion of the proposed investigation in which case the investigator will be given the opportunity to accept or decline such partial acceptance. In cases where two or more proposals address similar or complementary problems and/or adopt similar approaches to data analysis, the IUC may recommend to join the participation on part or total of two or more proponents into a single investigation proposal. In that case, when joint participation with other investigators is agreed to, a single individual will be designated as the Principal Investigator for the investigator group.

The VEGETATION Programme reserves the right to reject any proposal received in response to this Call for Proposal that would not be compatible or related to the objectives of the VEGETATION Preparatory Programme. Notice is also given of the possibility that any selection may be made either without discussion or after limited discussion with the proponents.

B.2 Evaluation and selection procedures

All proposals received by the IUC in response to this Call for Proposal will be initially screened to determine the relevance to the objectives of the VEGETATION Preparatory Programme and to determine if they conform to the instructions for proposal preparation. Proposals considered to be unresponsive to the stated objectives of the Call for Proposal will be returned to their author as soon as possible with a written explanation of the decision. They will not be considered further for the selection of proposals in response to this Call for Proposal.

The proposals considered to be responsive to the objectives of the Call for Proposal will be reviewed by the VEGETATION International Users Committee which could ask participation of individuals with widely recognized expertise in the scientific and technical fields covered by the VEGETATION mission. The purpose of this review will be to evaluate the scientific and technical merits of each proposal in terms of its strengths and its weaknesses, rating each evaluation criterion given in section 6.5.

Proposals having scientific merit will be reviewed to determine their technical feasibility and compatibility with the overall VEGETATION Programme.

Finally, the financial constraints will be included in the selection procedure, balancing the retained investigations as indicated above, taking into account the objectives of the VEGETATION Preparatory Programme, the specific fields which are are defined for this Call for Proposal and the necessity to insure adequate funding support to the most interesting investigations.

B.3 Treatment of proposal data

B.3.1 Commercial and Financial data

The commercial and financial data included in the proposals submitted in response to this Call for Proposal will only be used for evaluation purposes. Where it is the practice of a Principal Investigator or of his proposed subcontractors to treat certain commercial and financial data as a trade secret and such data is protectable as a trade secret under law, he may apply the Notice of the next section to those portions to be maintained as a trade secret.

In any event, commercial and financial data submitted in a proposal will be protected to the extent permitted under the law, either as a properly noticed trade secret, or as a commercial or financial information received from a person and considered as confidential or privileged.

B.3.2 Technical data

The technical data contained in any proposal submitted to this Call for Proposal will be used only for evaluation purposes. Where any such technical data constitutes a trade secret under the law and the proponent or his potential subcontractor desires to maintain trade secret rights in such technical data, the following Notice must be affixed to the cover sheet of the proposal specifying the pages of the proposal which contain trade secrets to be restricted in accordance with the conditions of the Notice. Technical data labelled in this fashion will be protected as a trade secret. CENTRE NATIONAL D'ETUDES SPATIALES, acting as the Maitre d'Oeuvre of the VEGETATION Programme or any other partner of the Programme will assume no liability for use or disclosure of any proposal technical data to which the Notice would not have been applied.

Notice :

Data on pages... of this proposal constitute a trade secret. It is (are) furnished in confidence with the understanding that it will not, without permission of the proponent, be used or disclosed other than for evaluation purposes. In the event a contract is awarded on the basis of this proposal, CNES, acting as the Maitre d'Oeuvre of the VEGETATION Programme may obtain, in the contract, additional rights to use and disclose this data.

B.4 Invention and data rights

Within the implementation of an investigation selected under this Call for Proposal, the Principal Investigator will be required to inform the Maitre d'Oeuvre (CENTRE NATIONAL D'ETUDES SPATIALES) within eight days of any patent or model request deposited for the protection of inventions which may result from the work performed.

Whenever the Principal Investigator may decide not to deposit such a patent or model request, CENTRE NATIONAL D'ETUDES SPATIALES as the Maitre d'Oeuvre of the VEGETATION Programme reserves the right to do so and, if so, in agreement with its partners of the Programme.

The Principal Investigator is required to grant the partners of the VEGETATION Programme a royalty-free license to use patents and models deposited as a result from the work performed within investigations selected after this Call for Proposal, provided he is free to do so and no major interest opposes to it.

APPENDIX C : TITLE PAGE FORM

VEGETATION PREPARATORY PROGRAMME

PROPOSAL for INVESTIGATION

TITLE :

TYPE OF INVESTIGATION :

Support to applications ❑ **Development of methodology** ❑ **Improvement of products** ❑

Thematic domain :

Geographical area :

PRINCIPAL INVESTIGATOR :
Title & Name :
Organization :
Address :

Telephone : **Fax :**
E.Mail :

CoInvestigators :

Name	Organization	Address	Phone / Fax / Email

Budget (in ECU) :

Period	Proposal Cost	Request	Data costs
Feb 95 - Feb 96			
Feb 96 - Jun 97			
Jan 98 - Nov 98			
Totals			

Reference to parallel or related proposals :

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE
Institute for Remote Sensing Applications
VEGETATION International Users Committee
Secretariat

VEGETATION

Ispra, May 18th 1994
VGT/PS/940518/2

"VEGETATION" onboard SPOT 4

PRODUCTS SPECIFICATIONS

Version 2 (05/18/94)

Prepared by G. Saint
Programme Scientist

Approved by JP Malingreau
Chairman International Users Committee

R Klersy, Y Trempat
Chairmen Steering Committee

R Klersy.

I-21020 ISPRA (Va) Italy Tel: +39-332-789765 Fax: +39-332-789536

VERSIONS

Version 0	02/11/93	Initial specifications
Version 1	03/02/94	Proposal for System Concept Review (to be approved by IUC)
Version 2	05/18/94	Include comments from the System Concept Review

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I. INTRODUCTION

The VEGETATION mission was defined to fulfill objectives which were described in (Ref. 4), detailed specifications derived from this definition being given in (Ref. 7). During the first meeting of the User's Committee in Brussels on 11/05/92 (Ref. 6), particular recommendations were given by the participants to define the products of the system:

1. the ground systems providing the VEGETATION different levels of products should complement the onboard instruments to provide to end-users the **operational service** which was initially defined as being one of the key aspects of this mission, They must provide **continuity of the service** on a long lifetime to be coherent with the planned uses (Ref. 7), especially monitoring of vegetation areas, both for production estimates and for studies related to interaction between the biosphere and the climate changes.

2. as many projects are now existing which will be important users of the system, strong interaction and coordination with these projects or with entities which are being set up to facilitate their realization must be provided in the first stages of definition and implementation :

   - the definition of products, either in terms of levels or for the algorithms to be applied for data processing, should be based on the needs of the existing projects or, when possible, on existing specifications of similar products, as soon as these definitions are widely accepted in the community of the potential users. Among existing projects, specifications designed by IGBP (Ref. 5) or by the international expert group of the Sahara Sahel Observatory (Ref. 8) should be the basis for detailed product definition. Other aspects on archiving consideration should also be based on work done for the definition of a number of data base systems dedicated to remote sensing data, for example a study done for the Centre Pilote d'Etude Spatiale de la Biosphère Africaine (CEPESBA, Ref. 9)

   - coordination with these projects for specific and adapted processing must be taken into account as soon as possible, either to provide better products suited to particular uses or to prepare, within the ground system itself, data sets or ancillary data that will allow more efficient uses of the VEGETATION data.

   - finally, to benefit from developing centers for archiving or data processing, creation of Specialized Processing Centers for particular products should be envisaged to optimize the task that should be undertaken by the VEGETATION ground system.

3. to fully benefit from the simultaneity of high spatial resolution and high frequency measurements provided by the HRVIR and VEGETATION instruments, adapted products to facilitate coherent use of both data types should be designed.

The following description of the products specifications should provide the capability for the entire VEGETATION system to ensure adequate service to the different types of users, building on existing knowledge and projects for the data to be integrated as soon as possible (within 3 to 4 months after SPOT 4 launch) in the global and regional data sets made available to the community.

During 1993, the International Users Committee set up a joint Working Group with the Integrated Project Team to refine and detail the definition of the products. The participation of the IPT insured realistic assumptions about the capabilities of the system and a clear understanding of product definition and operational constraints. The conclusions of this working group were presented to the IUC on Jan 24th 1994 and the general definition was approved. A survey on potential users of the VEGETATION system was performed during January 1994 : using the preliminary results of this survey, the most probable characteristics of requests as well as further details on the products themselves could be obtained and included in version 1. The general principles which had been defined in 1993 were confirmed and some new aspects were introduced :

- the products available from the VEGETATION system Ground Segment should be specifically designed for the use in studies on vegetation, providing as much coherence as possible with other data sets commonly used in these studies. The capability to adapt to important projects and to allow some evolution of the products delivered to users was again emphasized.

- the specifications apply to the data processing segment which is connected to the onboard system but are not mandatory for secondary receiving stations that will also have the capability to preprocess and deliver different products to users. However, it is strongly recommended that these secondary stations as well as other entities that would process VEGETATION data, be as much as possible coherent with the definition or algorithms proposed here, to ensure a wider use of these data, allowing comparisons, both for different regions and at different times. System parameters which are necessary for some of the corrections should be made available through proper arrangements.

- other possible data sets will not be made available as current products but some capabilities to provide them, especially for raw data sets, should be retained (for example under special agreement between the Ground Processing entity and users).

The System Concept Review held in Toulouse in April 1994 made some recommandations on the product definition which were included for a more detailed description of the different product levels.

This document is organized in two main sections : the first one presents the general structure of the products, with as much as possible justification or explanation of the choice of these products. The second section lists the specifications that should apply to the VEGETATION products.

II. MAIN FUNCTIONS and OVERALL ORGANIZATION

Four main functions have to be provided by the data processing segment to satisfy the general definition of the mission. These functions are the following:

- the generation and maintenance of a Core Archive which contains all the data received from the instrument system as well as the minimum ancillary data which are necessary to preprocess the raw data,
- the generation of enhanced products at different levels, both as basic products that should be made widely available and as particular products or information data sets that should be adapted to important projects,
- the maintenance of a catalogue of existing data, accessed through easy communication means to the users, to provide timely information on data availability and quality,
- the contacts with the users and projects to facilitate the use of VEGETATION products and the development of enhanced or new products, taking into account both the evolution of the needs of the community and the increasing capability to correct raw data for system or observational effects and to extract new informations.

A. GENERATION OF A "CORE ARCHIVE"

The basis for any other product generation is the data set composed of the original raw VEGETATION data as received from the primary receiving station and of all the system data which must be attached to the image data : calibration informations, geometric information on viewing conditions, location and datation of the images...

To allow further preprocessing steps, any information that could be used to characterize the conditions in which the data were acquired should be added and registered to the image and system data. Taking into account the existing knowledge and predicting what could be possibly done in the 10 or 15 years, the minimum set of ancillary data that should be appended to the image and system data is the following :

- **topography information**, using available digital terrain models with a resolution both in the horizontal plane and on the elevation which is compatible with the spatial resolution of VEGETATION and the needed accuracy both for accurate location of pixels and atmospheric corrections for constant gases absorption and Rayleigh scattering (Refs 1, 2). A possible model is ETOPO5 from NOAA/NGDC, but digital model under development should also be considered. The needed spatial resolution is about 1km while the elevation resolution is of the order of hundred meters.

  The topography information could and will most probably be used as information on slope and orientation of terrain for further corrections to take into account variations of sun illumination. In that case, the appropriate information might not be derived directly from the same topography model but from other sources more adapted to the estimation of slope and orientation for such a spatial resolution.

- **atmospheric conditions informations** : from present knowledge, the minimum information that should be provided is the standard climatic tables for ozone and water vapour concentration, aerosol optical depth with seasonal dependence. It must be noted that as research work is being done on the atmospheric corrections, other informations might be desired for future corrections : for example, distribution of water vapour derived from meteorological models or aerosol distribution measured from photometers networks. The use of these descriptions, which have to be updated regularly, will increase both the workload of the system (establish links with other centers for reception of the relevant data) and the volume of data to be archived. Ancillary data needed for an atmospheric correction using the experimental blue band should also be considered.

- **other information : TBD**

These data sets are not corrected but only annotated with all the information (system and other) that would be necessary for correction. Then, the geometric structure of this data set is identical to the raw data geometric structure and related to instrument viewing properties. No data should be deleted, for example data acquired on the same geographical location on the same day due to the overlap between successive orbits should be kept entirely.

To indicate the relevance of each measurement, a "status image" should be computed and added to the data : for each pixel of raw data, it should indicate a general category in the following set : cloud, snow/ice, water, land.

This Core Archive data set must be considered as the most basic data set of the system and archived from the beginning of the operational life with no limit concerning duration.

This data set is not made available to users, except under special agreement and for volumes that would have to fit the possibilities of the Ground Segment system.

B. GENERATION OF ENHANCED PRODUCTS

From the Core Archive, enhanced data products can be derived at different levels with increasing processing complexity and/or information synthesis. They have to be defined from characteristics which are common to many potential users to offer basic general products. Adapted data sets, either image or ancillary information data, should be made available to dedicated projects; interaction for the definition of these adapted products should also lead to the possible creation of Specialized Processing Centers, embedded or not in the projects, with particular connections to the data processing segment.

Two levels of enhanced products can now be defined, corresponding to the existing needs of potential users :

- VGT-P products correspond to data which will be mostly used by physicists for methodological development that could be embedded into applications using VEGETATION data.

- VGT-S products where some synthesis is applied on the "Core Archive" data to provide ground reflectances as well as some simply derived parameters.

In general, the products will be requested in advance, for selected areas and periods : users will require to be sent every data set acquired or generated on a regular basis. This characteristic is quite specific to the VEGETATION system for which very few requests will be done *a posteriori* using a catalogue of available data. However, the Integrated Project Team should take into account that some time will be needed after the launch of the system so that the users get acquainted with its capabilities and quality : the volumes given below for the different product levels are volumes that should be requested after this adaptation phase, which could last about one year.

1. *VGT - P* products :

Designed to be **used by physicists**, they can be defined as data that would have been acquired by an « ideal system ». The distorsions due to the system itself should be corrected to provide a product on which mission quality specifications apply (radiometry and geometry). The quantities which are provided are standardized to constant sun illumination on top of the atmosphere and will be scaled to equivalent Top of Atmosphere reflectances.

They must provide direct capability of registration between VEGETATION images acquired at different dates and between VEGETATION and HRVIR acquired simultaneously by instruments which are both on the same satellite, with the accuracy specified in the mission specifications.

The processing system should be able to process requests from the users giving:

1. the geographical location of their zone of interest,
2. the geographic projection to be used, selected among a set of available projections.

Data provided in return will consist of entire lines acquired on an orbital segment necessary to cover the geographical zone.

2. *VGT* - .*S* products :

VGT-S products take into account some **synthesis capability between successive orbits**, either on the same day or on different days : from the "Core Archive", data can be processed to extract the best possible measurement for a given period following carefully chosen criteria. Taking into account the existing uses of NOAA-AVHRR data and the definition of data used by projects, two types of standard products can be defined :

- a daily synthesis (**VGT-DS**), with ground reflectance and NDVI computed from the ground reflectances (this type of synthesis only takes into account multiple measurements obtained through the overlap between successive passes at high latitudes),
- a 10 day period synthesis (**VGT-PS**) similar to the composites already computed from NOAA-AVHRR data.

Both standard products are global on land and should be processed to provide a standard geometric sampling preserving the 1km raw data resolution. The cartographic projections to be used for that product should provide as much coherence as possible with projections generally used either at regional or at global level.

Synthesis should be done through selection of the best measurement acquired during one day or one decade : the most commonly used method is the maximum composite value selection which retains the measurement corresponding to the highest NDVI value computed on top of atmosphere reflectances. This selection method tends to decrease atmospheric condition influence and appears to be the best known method to get rid of the worst atmospheric conditions, but ground directional effects are not taken into account (Ref. 10). The compositing methods will have to be reviewed and updated as new methodologies are validated, especially when directional effects can be modelled and integrated into the composition technique.

As these products will most certainly be the most frequently required product, even for retrospective studies, they both should be archived in a « Global Archive ».

During a transition phase (18 months to 2 years), degraded resolution products should be made available while users are developping their own capacity to handle the VEGETATION data sets.

The processing system should be able to process requests from the users giving:

1. the spectral bands (including known indices, NDVI at the beginning) that should be included in the product,
2. the geographical location of their zone of interest,
3. the geographic projection to be used, selected among the set of available projections.

C. CATALOGUE INFORMATIONS

The catalogue should be organized so that users could have some on line access to

- information on existing data, their level of processing, their quality,
- an interactive display of the status image of each of these data with browsing capability,
- for the global 10-day synthesis, a status image should present for each pixel its current status : valid ground measurement or still cloudy or with "bad" atmospheric conditions in the current period (**TBD**),
- an indication of available HRVIR images (to be studied and defined with SPOT Image),

- the ordering system as well as information of the status of the processing of their orders.

To provide these capabilities, different solutions might be developped and implemented, from a plain text catalog to a fully graphic catalog, with quick look images, full references to both VEGETATION data and High Resolution images... Taking into account the type of request which will most frequently be done *a priori*, the users will not in general need a full graphic display of images in real or near real time. The development of a highly sophisticated graphic catalog should probably not be a priority for the system, except if the need for real time information on the VGT-PS is needed for users that would like to order the product before the end of the period if a sufficient portion of their area is cloud free.

A periodic edition of a catalog of quick look images (similar to VGT-PS4 or PS8 for sampling with full information on quality and cloudiness) must be implemented for historical studies. This catalog should be available on a support like CDROM for easy handling.

D. CONTACTS WITH USERS AND PROJECTS

A close contact between the VEGETATION data processing segment and its users should be provided to ensure the full use of the system capabilities.

1. Evolution of product nature and quality

During the study for the definition of a standard processing system for OSS (Ref. 8), a recommendation was given from the beginning on the need to allow evolution of the processing methods applied to the data : while providing some *continuity* of the service, it is essential that the data processing segment be able to integrate *newly developed and validated methods* for data correction. These methods will be developed by the users community, either from experience gained on the VEGETATION data themselves or from experiments on other sensors : for example, some enhanced methods to address directional effects should come from the use of the POLDER sensor onboard ADEOS (launch in 95) as well as from the sensors that will be available onboard the EOS systems (MODIS, MISR...). As it is known that the proposed processing algorithms do not fully correct or take into account for atmospheric or directional effects, any evolution of the system that will allow a better use of the VEGETATION data should be integrated into the system.

Two particular enhancements should be available and implemented some years after the beginning of VEGETATION acquisitions :

- on atmospheric corrections: it is expected that the experimental blue band will allow development of new algorithms for evaluation of aerosol effects on the other spectral measurements. From ongoing studies and possibly from the use of other sensors, ground measurements (photometers networks) or atmospheric circulation models could also provide new ancillary information that should be included into the "Core Archive".
- on directional effects: these effects can be seen as noise affecting the signal or as possible source of new information on the nature of the ground cover. As VEGETATION will provide measurements taken with different viewing and solar geometry on short periods of time (one day for high latitudes or some days for

tropical zones when atmospheric conditions are good), any new algorithm allowing either the correction of these effects, especially for the 10-day synthesis of the "Global Archive", or the definition of a new product where measurements acquired with different viewing conditions would be the basis for new informations, should be taken into account and considered for possible implementation.

The same evolution capability should also be provided for the nature of support of the products : the standard supports are evolving very rapidly, with increased capacity which will be more adapted to the volume of data generated by the VEGETATION system. Connections through international public networks will also see large increase in their capacity which will be able to ensure timely distribution of the products, especially for projects requesting frequent and high volume data sets.

3. "Non-data" products

As in all the other systems involving distribution of large volume data sets, data access and processing is generally time consuming, both during the development and operational phases. To facilitate the use of VEGETATION data, methods and standard software (for the most common computer systems) should be made available to users, projects, Specialized Processing Centers and the secondary receiving stations (Ref. 9). The knowledge which will be accumulated during the development phase and by users of the data sets should be referenced to allow exchanges both between the data processing segments and its users and between users.

E. OVERALL ORGANIZATION

The relationships between the different levels of products and the access that should be provided to users are presented in Figure 1. The general characteristics presented above show the central role of the two archives : the "Core Archive" from which any other data set is derived and the "Global Archive" which stores the enhanced data that should be the most widely requested.

The "*Core Archive*" will be the basis for the entire system as well as for scientific uses dealing with basic properties of the VEGETATION measurements.

The "*Global Archive*" will be the focus product of the entire VEGETATION system : the first priority for the data processing segment development should be to provide the easiest access to that product, both for *a priori* requests and for *a posteriori* requests through the catalogue (browsing capability), and ensure the best quality control both on product generation and on distribution through adapted means.

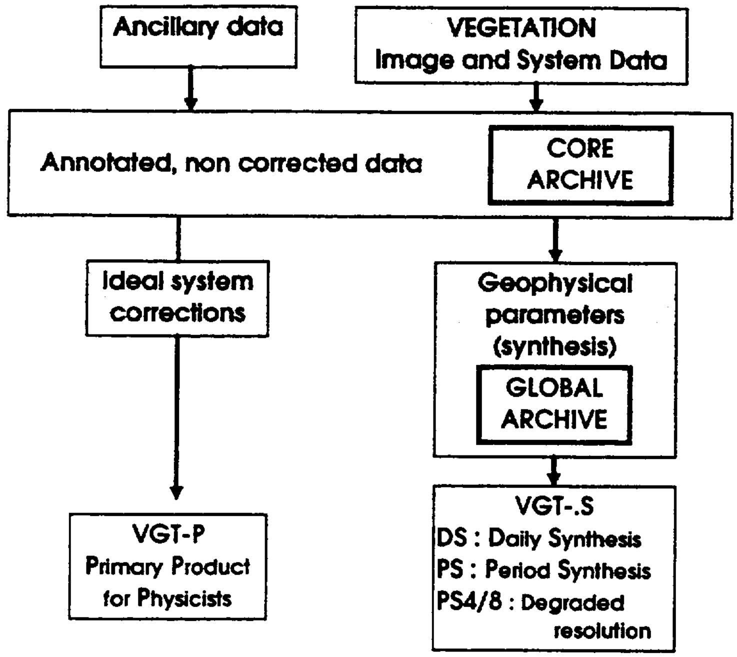

Figure 1 : Overall flowchart

III. PRODUCT SPECIFICATION

The above products are defined in terms of algorithms that should be applied for correction, nature and format of the data sets, volume and delivery time that should be provided as well as requesting information that would be used as controls for processing.

A. INPUT DATA FROM THE VEGETATION ONBOARD SYSTEM

The input to the VEGETATION data processing segment will come from the onboard system and the Vegetation Control Center. They must be :

- the four spectral bands measurements with proper reference data on acquisition time (time of measurement)...
- satellite characteristics : orbit parameters for determination of position and attitude, instrument parameters for geometric location...
- calibration coefficients for the four channels and all detectors

B. *VGT - P* PRODUCT :

The input system data will be processed using ancillary data necessary for radiometric and geometric corrections and annotation of the data set. The ancillary data include both system informations and external informations as described below.

The quality of VGT-P data must meet the specifications given for the mission (Ref.7)

The output data will correspond to the entire lines of the orbital segment which is necessary to overlap the geographical area requested by the user.

1 Radiometric corrections

Calibration information will be used to correct for detector normalization, absolute calibration and output values will be linearly related to equivalent « Top of the Atmosphere » reflectances. The linear relationship should use a null offset and a spectrally constant scaling factor allowing direct comparison between spectral reflectances. The quantization error should be coherent with the specified Noise Equivalent Reflectance. No saturation should be found at least for the specified ranges for each spectral band and, if possible, reflectances higher than the maximum specified range should be coded even if the radiometric quality does not meet the radiometric specifications.

Missing measurements should be corrected or indicated as follows :

1. interpolation using the mean value of their two neighbours should be used on the blind detectors in the SWIR spectral band,
2. identified « false detectors » in the VIS-NIR spectral bands should be interpolated the same way,

3. lost lines should not be replaced through interpolation,

4. interpolated and « missing » measurements should be flagged in the status map.

2 Geometric corrections

All pixels should be resampled onto a regular grid, taking into account :

1. spectral band registration,

2. satellite location and attitude correction (ground control points should be used if necessary to ensure the specified accuracy at mission level)

3. terrain elevation (from available global Digital Elevation Model, ETOPO5 **TBD**) to take into account parallax distorsion and provide orthoimages.

The regular grid should be defined using a small set of projections (10 to 12 **TBD**), for either global or regional mapping. **It is however essential that the set of projections chosen for the VGT-P products be compatible with the set of projections available for SPOT high resolution images to ensure direct registration between VEGETATION and HRVIR data.**

A final 1km resampling grid is required when the projection is adapted to such regular sampling.

3 Status map

A status map will be provided with the images, indicating for each pixel one of the following cover classes at the time of acquisition:

1. land or water (sea, lakes...) : it could be obtained from location information and reference maps,

2. snow, ice or cloud : they should be obtained at first from the spectral information. As complementary studies are necessary for a detailed definition of the algorithms, provisions should be made during the development of the ground segment to introduce methods that could be obtained through specific studies performed as part of the VEGETATION Preparatory Programme. Two approaches could be envisaged :

    - to use existing threshold algorithms adapted to the available spectral bands.

    - to use seasonal statistics on spectral measurements as a basis for theshold definition. These statistics should come either from analysis of NOAA-AVHRR data or from the first year of exploitation of VEGETATION data.

The capability to use cloud cover maps derived by meteorological services should also be studied.

It is important that a minimum valid information on declared cloudy pixels be included in the situation map : existing algorithms should be adapted to provide the least percentage of pixels flagged as cloudy while they actually are not, even if some proportion of actually cloudy pixels are not flagged. The performance of such algorithms should be discussed with the IUC for approval.

Indication of interpolated, lost pixels or lines should be part of the status map, even when it is spectrally dependant.

4 Ancillary data

The following information will be provided :

system information

1. methods and data to associate to each pixel its location and acquisition time as well as geometry of acquisition (solar zenith and azimuth angles, viewing zenith and azimuth angles, with an accuracy of around 1 to 2°)
2. reference to actual absolute calibration parameters used to allow reverse correction assuming the correction is linear.

atmosphere information

The standard correction method for all VEGETATION products will be based on SMAC (see Ref 12). Then, all necessary data for application of SMAC should be appended as ancillary data :

1. vertically integrated gaseous contents for water vapor and ozone,
2. aerosol optical depth at 550nm.

The IUC and Integrated Project Team together will analyze the capabilities of existing meteorological systems to provide these data coherently with the delivery time specified for each level of product. The sampling of these data will be adapted to existing data sets and coherent with other grids giving different type of ancillary information (geometric conditions...) : a typical sampling size would be of the order of 0.5° or a regular grid of 50 km or less spacing. In the case where actual values are not available in time for inclusion in the data flow during the operations, assumptions on values that should be used will be inferred from climatological tables.

The Integrated Project Team should make provision for evolution of the system taking into account possible use of

1. the blue band from which information on aerosols effects could be extracted. The blue band could be used for computation of the aerosol optical depth at 550nm or a standard algorithm to infer aerosol effects from the blue measurements could be indicated.
2. measurements acquired by regional networks for the determination of atmospheric properties. As some of the most important regions for the mission of VEGETATION will be covered by such atmospheric parameters estimates, this capability should be incorporated even if it cannot be made on a global basis.

topography information

the Ground Segment should at least indicate a reference to the elevation information data set that will be used for the geometric corrections. The users will then have the capability to retrieve topographic information from the known location of each pixel.

5 Elements for product request

To order a particular VGT-P product, users should have to specify (directly or via the interaction with a catalog) the following elements :

1. date and reference to the orbit path from which data should be obtained,
2. the geographic location of their zone of interest. If it is necessary to simplify the project development, the requested zone could have to be composed of an integer number of predefined 1000x1000km^2 scenes, but the image data should be arranged into only one image.
3. the geographic projection to be used, selected among the set of available projections.

No capability to deliver products containing only a subset of the original spectral bands collection and ancillary information should be made available.

6 Data volume and delay requests

The estimate of the volume of data to be distributed each day is corresponding to

- around 2 global land coverage per day for *a priori* requests with a delivery time of 2 to 4 days after acquisition,
- around 1 global land coverage for *a posteriori* requests, with a delivery time of about 1 week after the request.

NOTE : some areas might be requested several times while others would be requested only once.

For these products, as they will be mostly used for methodological development on a regional basis, the typical size of the area which will be requested by a particular user is between 10^6 and 25 10^6 km^2.

C. *VGT* - S PRODUCTS :

Level 3 products are extracted from the "Global Archive", either for the daily or decade data set.

The daily synthesis (VGT-DS) is computed from the different passes of one day on each location, each pass corresponding for high latitudes to different viewing angles.

The decade synthesis (VGT-PS) is computed from all the passes on each location acquired during 10 day periods. The periods will be defined according to the legal calendar : from 1st to 10th, from 11th to 20th, from 21st to the end of each month.

The quality of these products will be derived directly from the quality of VGT-PS products, so no particular new specification is given for them.

At this stage, synthesis between different passes must be performed selecting the best measurement of the period defined from the following criteria :

1. it should not correspond to a blind or interpolated pixel,
2. it should not be flagged as cloudy in the status map (snow covered pixels are considered as candidates for the selection),
3. it should correspond to the highest value of Top of Atmosphere NDVI. However some other choices should be considered for later decision by the IUC : either the highest sun illumination or the closest to nadir.

The IPT must consider the capability to change to a better selection procedure or algorithm, but most probably change will occur only after 18 months to 2 years of operation of the VEGETATION system (experiments and wide approval by the user community)

1. Full resolution products

for each pixel

1. ground surface reflectance in the four spectral bands corresponding to the selected measurement, the atmospheric correction being performed using the annotations of VGT-P corresponding data and SMAC procedure (Ref. 12),
2. Normalized Difference Vegetation Index. This should be considered as a first example of a widely accepted surface parameter, and capabilities to include other quantities derived from surface reflectance should be preserved in the system. However, the definition of such new parameter will most probably not be available before some exploitation of the VEGETATION system itself.
3. geometric viewing conditions (similar to VGT-P product but it must be indicated for each pixel),
4. reference to date and time of selected measurement,
5. information on the composite status map.

for each data set

- references of all corrections applied for calibration, atmospheric correction and geometric processing.

The geometric projections should be taken in the same set as for the VGT-P products.

However, to reduce the amount of processing to adapt the projection to any request, it could be envisaged to choose one projection as the basic global projection from which all the other projections would be recomputed. The basic projection should then be a Plate Carrée projection leading to a sampling interval of 1km at the equator. This basic projection will be made available as a product to users, as well as derived products that will be obtained with different projections, through resampling using nearest neighbour replacement.

2. Degraded resolution products : *VGT-PS4 & VGT-PS8*

To ensure some continuity with existing projects and allow some training time, degraded resolution products should be made available, at least during the first two years of operation. They should be resampled from the VGT-PS product, with grid sizes of 4 and 8 km. The resampling should be performed selecting always the same pixel in the 16 or 64 $1km^2$ pixels.

3. Elements for product request

To order a particular VGT-S product, users should have to specify (directly or via the interaction with a catalog) the following elements :

1. date/reference to the day (for VGT-DS) or period (for VGT-PS) from which data should be obtained,
2. the geographic location of their zone of interest. If it is necessary to simplify the project development, the requested zone could have to be composed of an integer number of predefined $1000x1000km^2$ scenes, but the image data should be arranged into only one image.
3. the geographic projection to be used, selected among the set of available projections.
4. the subset of the original information collection (for example, the entire set of data or only NDVI with ancillary data or any subset of spectral bands...)

4. Data volume and delay requests

This product, especially the VGT-PS product, will certainly be the most requested product for large area coverage : some regional areas will be requested several times and regularly throughout the year. The total volume of requests averaged for each product instance is estimated to be :

- about 6 to 8 global land coverage for VGT-DS and *a priori* requests, with a delivery time of 2 to 4 days,
- about 10 global land coverage for VGT-PS and *a priori* requests, with a delivery time of less than 1 week,
- about 5 global land coverage for VGT-PS and *a posteriori* requests, with a delivery time of less than 1 week,

- a maximum of 10 global land coverage for both VGT-PS4 and VGT-PS8 for *a priori* requests and with a delivery time of less than 1 week. (transition phase)

This volume can be decomposed in a large number of regional requests (10^6 - 25 10^6 km^2) and a limited number of global requests (rarely one for VGT-DS, between 1 and 2 for VGT-PS, between 2 and 5 for VGT-PS4 & VGT-PS8)

E. SUMMARY ON REQUESTED VOLUMES and DELIVERY TIMES

The following table summarizes the estimates of volumes requested each day for each data product and mean delivery time.

Product Name	Nature	Zone	Type of request	Volume (1)	Mean delivery time (2)
VGT-P	« Ideal system » corrected data	Orbit segment	*a priori* *a posteriori*	2 1	2-4days <1week
VGT-DS	Daily synthesis	Geographical zone	*a priori*	6-8	2-4days
VGT-PS	Period synthesis	Geographical zone	*a priori* *a posteriori*	10 5	<1 week <1 week
VGT-PS4 VGT-PS8	Degraded resolution	Geographical zone	*a priori*	<10	<1 week

1: volumes are estimated in total global land coverage (some portions can be ordered several times). It corresponds to different volumes in bytes for the products.

2: delivery time is running from acquisition date for *a priori* requests and from ordering date for *a posteriori* requests.

Table 1 : Estimated volumes and delivery times for each category of product.

F. GENERAL SPECIFICATION FOR DATA FORMAT and SUPPORT

F.1 Format

The format for any product level should conform to the "Standard Family Tape Format" used widely for satellite remote sensing data, the evolution of the definition of other structures (HDF for EOS for example) should be studied by the project development team to propose the highest compatibility with other systems. In any case, as stated above, the algorithms and software (for the most common computer systems) should be made available as templates for these users to develop their own input/output software.

The format might be adapted to the support, especially to transmission via telecommunication lines: compression techniques might be applied, providing they are lossless compression or compatible with the radiometric quality when specified. In case of compression, capability to extract data from specific geographic areas or at different resolution would be appreciated.

F.2 Data coding

Coding should always be made on multiples of bytes and avoid intermediate number of bits (10,12...)

F.3 Supports

The support for data delivery must be adapted for the volume to be delivered and to particular constraints on time delay : the most standard and compact support should be proposed (from CDROMs to Exabyte cassettes for example, taking into account durable new standards which are flourishing) as well as network links which should be proposed when cost / effectiveness can be accepted by the users.

G. CATALOGUE

The main purpose of the catalogue will be to give information for *a posteriori* requests where users would order VEGETATION data which were acquired before the time of ordering. For *a priori* requests, the processing should be done without any interaction with the « customer » as soon as the characteristics of the request are accepted both by the customer and the Image Ground Segment entity.

To allow short term (between 6 month to one year) retrospective requests, an on-line catalogue must be available giving only quality information for all products which can be ordered. For longer term retrospective studies, it will be much easier to make available on « standard » supports a periodic catalogue, where « simplified » or « quick-look » image data could be appended to the quality information.

1. On-line catalogue

As a first implementation the catalogue should give access at least to information on the quality of the images (similar to the indications given in the status map, with or without cloud indication if no widely accepted method is retained), with indication of existing High Resolution data that could be ordered from SPOT Image. If a character mode catalog can synthetize the usefull information it could be acceptable. A simple graphical representation of information should however be preferred, and be designed to be coherent with standard Graphical User Interfaces available when SPOT 4 is launched.

Access to the catalogue must privilege the use of international networks connections.

As its main purpose will be for user to define *a posteriori* requests, procedures to establish a request and give all informations on the status of a particular request should be embedded or closely related to the catalogue.

2. Periodic catalogue

A periodic catalogue of VEGETATION data should be made available (on CDROM for example). It could be based on a sampled image (8km sampling) of red, near infrared and short wave infrared images in a standard graphical format for images and an indication of cloudiness computed from the status map (number of cloudy 1km pixels in the 8 km pixel) if the information can be obtained. This catalog should be edited every 6 or 12 months for the VGT-DS and VGT-PS products.

H. OPERATIONAL CONSTRAINTS

Apart constraints inferred from the characteristics of the products, the projected volume that could be ordered and the delivery time for each category, the development of the system should take into account the capability to evolve in response to the users community.

Particular attention must be given to the first year of the operational system, where users will most certainly place *a posteriori* orders, assess the quality of the data, products and services before they begin to place *a priori* orders. Then Table 1 must be considered as the profile of requests after the users community has got acquaintance with the entire system and operational projects which could make profit from the VEGETATION data have adapted their own system to operationally ingest these data. The time needed for such adaptation can be estimated to be around one year. One of the roles of the VEGETATION Preparatory Programme is to shorten and facilitate this phase as much as possible.

A second type of evolution that must be taken into account in the design of the system is the regular update of its procedures for data processing. As it was already mentionned, the availability of VEGETATION data will allow development of new methods for extraction of information or better processing. Some areas are already known as being only acceptable for a first implementation of the system, mainly the cloud detection and the synthesis procedures. However, the only way to improve these procedures is to process a significant amount of good quality data which will only be available from VEGETATION itself or systems that will provide measurement collections at almost the same time. Then capability to change some procedures must already be designed, especially for the two procedures mentionned above.

As a consequence, when the standard procedure is changed, solutions for keeping the coherence between products along the entire lifetime will have to be found : the reprocessing of the archive is a major task to undertake that should not be considered in the scope of the Image Ground Segment entity. At one particular time, the procedures to be applied for the production of any data sets should only be the current procedures, with the parameters which are appended as ancillary informations to VGT-P products. Processing data with a procedure which is not the current procedure at the time they are processed should not be considered as a priority for the Image Ground Segment entity and possible external facilities could be negociated for these particular tasks. The capability for such tasks should then be studied specifically, the decisions related to a general or partial archive reprocessing being taken in conjunction with users representatives in a manner similar to what is used for the first specifications of the products.

REFERENCES

1. "Surface reflectance retrieval using atmospheric correction algorithms" P.M. Teillet. Proceedings of 1989 International Geoscience and Remote Sensing Symposium IGARSS 1989, 864-867.

2. "Rayleigh optical comparisons from various sources" P.M. Teillet. Applied Optics 1990 28: 1897-1900.

3. "Map projections : Theory and Applications" F. Pearson CRC Press Inc. Boca Raton Florida 1990

4. "A mission for global monitoring of the continental biosphere" F Achard, JP Malingreau, T Phulpin, G Saint, B Saugier, B Seguin, D Vidal-Madjar Jan 92, available at LERTS.

5. "Improved Global Data for Land Applications" IGBP report n° 20, 92

6. "First meeting of the International Users Group for VEGETATION/SPOT 4" Th. Phulpin 11/17/92 CNES S4.CR.36-1566-CN

7. "VEGETATION onboard SPOT 4 : Mission specifications" Version 3 G. Saint 05/18/94

8. "Final Report of the OSS Working Group on NOAA-AVHRR Standard Preprocessing Definition" A. Faizoun 11/92 Ref : OSS /41/AF Paris

9. "Centre Pilote pour l'Etude Spatiale de la Biosphère Africaine" Rapport au Comité des Programmes Scientifiques du Centre National d'Etudes Spatiales 04/92

10. "Comments on radiometric and geometric corrections in AVHRR compositing", personal communications from J. Cihlar and G. Dedieu 1993

11. Report on the VEGETATION International Users Committee held on Jan 24th 1994 at IRSA/JRC Ispra

12. "SMAC : a simplified method for the atmospheric correction of satellite measurements in the solar spectrum" H. RAHMAN, G. DEDIEU Int. J. Remote Sensing, 1994, vol.15, no.1, 123-143

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE
Institute for Remote Sensing Applications
VEGETATION International Users Committee
Secretariat

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"VEGETATION" onboard SPOT 4

MISSION SPECIFICATIONS

Version 3 (05/18/1994)

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VERSIONS

(see Annex D for a list of modifications)

Version 0...	06/30/92.......	Initial specifications
Version 1...	01/12/93.......	Specifications discussed and proposed by the User's Committee meeting, Brussels 11/05/92 (Ref :CNES S4.CR.36-1566-CN 11/17/92)
Version 2...	04/15/93.......	Includes comments made during the User's Committee meeting, Brussels, 03/22/93
Version 3...	05/18/94.......	Includes recommandations from the System Concept Review, Toulouse, 04/21/94

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I. INTRODUCTION

A. CONTEXT OF THE PROPOSAL

The concepts of an instrument dedicated to studies of the vegetation cover on a global basis was presented to CNES in 1985 as a candidate to complement the main SPOT 4 mission that is based on two high spatial resolution instruments. The overall objectives of "Vegetation" were to provide accurate and operational measurements of simple characteristics of vegetation canopies,

- either for scientific studies involving both regional and global scales experiments on long time periods (for example development of models of the biosphere dynamics interacting with the climate models),
- or for systems designed to monitor important vegetation productions, like crops, pastures and forests.

Since 1985, a large number of scientific and technical teams have been involved in the use of meteorological satellite data (such as NOAA-AVHRR or METEOSAT) for studies of vegetation characteristics, taking benefit of the repeatitivity of the system that allows an acquisition frequency adapted to the vegetation seasonal evolution rate, and of the possible global coverage with a spatial resolution varying from 1 to about 16km.

These studies provided much more knowledge of the possibilities of remote sensing to determine surface characteristics. They also played a key role in the development of global scale projects dedicated to the functioning of vegetation covers, their role in environmental and climate changes and their interaction with the atmosphere. Obviously, the relationships between remote sensing measurements and detailed parameters of biosphere processes are still to be established to reach the level of *in situ* studies, but it is also clear that even simple and robust estimates of main parameters —as reflectance of the solar energy or absorption of photosynthetically active radiation for example— can provide a much improved knowledge of the biosphere dynamics, both at regional and global scales. One key requirement for this simple data collection is that it is available for long periods of time (related to time response of the seasonal and climatic evolution), with a minimum and constant guaranteed accuracy or with complement measurements to allow some separation between target characteristics and disturbances due to its environment. Another important requirement is that the capability to migrate from local to regional then to global scales be provided, without the problems related to differences in time or environment conditions of the acquisition.

The "Vegetation" system, composed of an instrument onboard a satellite and of its associated ground segment, has the objectives to provide these long term simple measurements adapted to biosphere studies. Capabilities for scale integration are provided by the combination with the main SPOT instrument (HRVIR) which allows high spatial resolution for detailed modelling activities or multilevel sampling procedures. Availability of data to different types of users is permitted through the centralisation of reception and archiving global data, associated to quality monitoring. The launch date (around 1996) and duration of the system (about 5 years of estimated life time) is adapted to a systematic and extensive application of methodologies that are existing or will be developed in the next five years.

Evolution of the system.

Clearly this system will benefit from detailed studies based on other systems that are dedicated to specific studies of the characteristics of remote sensing measurements or to their relationships with surface or processes' parameters. It must be envisaged that the evolution of the mission specifications will have to take into account results of such studies to provide improved characterisation of the biosphere state and dynamics. Moreover, as many research activities and projects are being developped around the use of VEGETATION type data, new methodologies will certainly be validated to invert surface parameters from remote sensing measurements (for example estimation of absorption of photosynthetically active radiation): these methodologies must be taken into account in the evolution of the system, both during the time life of the ground segment associated to the initial onboard instrument and for following instruments that would continue the same type of mission.

B. PURPOSE OF THE MISSION SPECIFICATIONS

A detailed description of the domains that could benefit from this system is given in "A mission for Global monitoring of the continental biosphere" (Ref. 13). In this document, the mission objectives will be described and structured, to emphasise on the requirements of the system in terms of "data" characteristics, accuracy of their different aspects (radiometry, geometry) and constraints for operation of the system.

The particular data to which these quality specifications apply will be described. A strategy to define derived data products adapted to potential users will be outlined. The requirements for these derived data products should be defined by a User Committee, leading then to the definition of the part of the ground segment that must transform system products to users products.

Geometry and radiometry characteristics and their desired accuracy will be given. Particular attention will be given to the correlation to the high spatial resolution instrument characteristics to preserve one of the essential feature of the entire system.

Constraints for operation of the system, availability of data to users will be expressed.

II. MISSION OBJECTIVES

The domains for which that system is defined are described in Ref. 13, leading to a general description of the instrument characteristics. However, to precisely determine the specifications, the different uses that will be done of the data delivered by "Vegetation" have to be structured in order to give common constraints on all aspects of the measurements. This will show that a synthesis can be drawn, giving a minimum set of specifications for geometric and radiometric characteristics as well as for their accuracy.

A. RATIONALE FOR THE GENERAL DEFINITION OF THE SYSTEM

Mission based constraints

As mentioned above in the introduction, the objective is to provide simple and robust data adapted to biosphere studies : as the first order characteristics of land cover can be derived from a minimum set of remote sensing measurements, a number of goals relating to vegetation monitoring can be achieved if long term data sets are available to users with a minimum and guaranteed quality. The following discussion, referring to studies conducted in the last years, will summarise the concepts and justifications for that approach.

Wavelength domain	Measurement set for the next years	Improvements
Solar reflection : VIS/NIR/SWIR	• 3 spectral bands : VIS, NIR, SWIR • Additional bands for atmospheric corrections • Directional measurements (and/or polarisation)	• Active systems (lasers) • High spectral resolution • Polarisation On board preprocessing
Thermal infrared	• 1 to 3 spectral bands between 3.5 and 14 µm • Vertical sounder	• Active systems (?) • Spectroscopy
Active/ passive microwaves	• The largest wavelength with acceptable spatial resolution (passive microwaves)	• Enhancements of the spatial resolution (interferometry for passive microwaves)

Table 1 : Remote sensing measurement sets for biosphere studies

The rationale for the definition of general characteristics of the proposed system was developed in Ref. 9 (pp 65-75). Taking into account the different processes (exchanges between vegetation and soils, between vegetation and atmosphere, production mechanisms and ecosystems dynamics) and the scales —spatial as well as temporal scales— that have to be studied for a better understanding and then modelisation of the biosphere, different sets of measurements were detailed (table 1).

The "ideal" spatial systems that could contribute were outlined (table 2). They should be composed of two different satellites; each adapted to some specific measurements :

- a "mid morning" satellite for short wave measurements in the solar reflection domain, the reason for overpass hour being related to cloud cover which is statistically better at that time than in the afternoon when convection generally gives cumulus clouds in the tropical areas,
- an "afternoon" satellite for the studies of energy and water fluxes using mainly thermal infrared instruments.

"Mid-morning" system	**"Afternoon" system**
Core instruments : wide FOV instrument (with 1 km spatial resolution) and high spatial resolution instrument (≈ 10-20m) with same spectral bands **Options** : thermal IR radiometer and spectrometer **Orbit** : sun-synchronous **Time** : 9h30 (solar) **Cycle** : global coverage each day	**Core instruments** : Thermal IR radiometer, IR spectrometer, atmospheric sounding **Options** : wide FOV VIS-SWIR microwave radiometer (10.7, 18.5, 37 GHz) imaging scatterometer (5.5 GHz) **Orbit** : sun-synchronous **Time** : 13h30 and 1h30 (solar) **Cycle** : global coverage

Table 2 : "Ideal" satellite system for biosphere studies

Different options were discussed, mainly about thermal infrared measurements : two types of information can be extracted from thermal infrared data : surface temperature and surface emissivity —with appropriate hypothesis for decoupling these two characteristics—.

- surface temperature is one of the keys to the determination of energy and water fluxes. However, it is certainly desirable to get thermal data at least on the minimum or maximum values while a single measurement in the transition period (mid morning) might be difficult to interpret due to the variability of the factors that can cause different temperature elevation rates.

Then the best choices for thermal data would be either at the maximum temperature level (generally beginning of afternoon), or to use the geostationary meteorological satellites that provide adapted time sampling (about twice an hour) with spatial resolution that are in the range of about 5–10 km. Other needs of spatial resolution of about 30 m and several acquisition times during one day have still to be refined.

- surface emissivity might be one way to identify surface characteristics but it was considered that methodologies to extract useful information on emissivity had still to be validated. As in the solar radiation domain, the applications that could take advantage of emissivity estimations need a high spatial resolution. Existing technologies are still limited to provide such measurements in the near future.

Technological constraints

For the final specifications, limitations due to technology will impose strong correlation between different features, for example : getting a global coverage with a specified frequency of acquisition for a sun-synchronous satellite imposes a particular field of view of the instrument. For a desired spatial resolution, number of spectral bands and number of digitisation levels, this will determine the volume of data to be transmitted and the data rate, then the characteristics of the transmission systems that can be used (type of receiving station).

It was also considered that some choice had to be made to insure that measurements would be acquired as soon as possible. The opportunity to have such a mission onboard SPOT 4 was certainly one main factor for decision : some developments would not have been feasible in the time left for design and development before launch (thermal infrared for example), and limitations on weight, energy consumption and volume had to be taken into account.

Mission constraints were then traded against feasibility to insure availability of measurements as soon as 1996. Considering the operational and simple concepts which were retained for the general definition, while some simple characteristics (other spectral bands for example) had to be abandonned, the overall system keeps some coherence. It must be kept in mind that evolutions will have to be proposed and discussed as stated above, both on the ground segment of the first system and for the second instrument.

1. TYPICAL USES ON VEGETATION

From this rationale, and participating to the international development of studies of the biosphere, the needs for a vegetation mission were detailed, being consistent with the main recommendations also expressed in Ref. 16. Three typical uses could be outlined :

- **surface parameters mapping** : this is the basic need, especially for climate and meteorological studies where boundary conditions have to be prescribed for example to General Circulation Models or forecasting models. Factors such as surface roughness, albedo, heat exchanges —sensible and latent— are important variables for these models and they can be determined from "simple" identification of land cover. Their seasonal and long-term variations are related to vegetation dynamics and the capability to identify physical characteristics of land cover is a key to accurate prescription of these variables. Scales addressed in GCM or forecasting models (typically about 100 km) request that land cover and its variability must be determined with a sampling of about 8 to 10 km (Ref. 17) : the basic spatial resolution needed for identification of land cover and its variability is 1 km. The IGBP requirement introduces the need for *elementary zones* (blocks of about 10x10 km) on which radiometric properties should be specified for a more accurate analysis than on larger blocks (zones of about 1000x1000 km for example)
- **agricultural, pastoral and forest production** : since the beginning of the land surface satellite remote sensing era (1972), important projects (for example LACIE, AGRISTARS for USDA, MARS for CEC, TREES for ESA...) have been set up to develop methodologies and strategies to use remote sensing data either for mapping of land use in anthropogenized or natural ecosystems or for estimation of production potential. Their specific objective was to determine the evolution of productions. This objective had to be adapted for management of crop production for agricultural exporting countries, to monitoring of pastoral resources and their dependence from meteorological evolutions, to the evaluation of possible global impacts of deforestation and more generally to the needs of information related to political or social orientations and decisions. One strong model that should be used to infer specifications for the vegetation system is the MARS project, especially because of the structure of the project itself that is based on complementary approaches using ground surveys, high spatial resolution (SPOT and Landsat/TM data) as well as frequent observations (NOAA/AVHRR) and classical agrometeorological models.
- **terrestrial biosphere mechanisms monitoring and modelisation** : the contribution of the continental biosphere to the biogeochemical cycles (exchanges of carbon and other trace gases) and to water and energy exchanges is one of the objectives of the development of models. Interaction with human

activities is also one of the main points to be studied, because the effect of human pressure on the biosphere might be one of the means by which man is acting on climate on the long term. Biosphere processes and land cover characterisation are the basis for quantification : estimations of land cover variables as well as the dynamics of these variables have to be made for a good understanding leading then to modelisation. Predictions of impact of climate change on the biosphere and of interactions of the biosphere with the climate — either due to natural factors or to human pressure— can only be inferred from quantification and formalisation of the mechanisms by which vegetation cover and ecosystems are functioning. Multilevel series of models have to be developed and linked, ranging from ground studies, local parameterisation and models to regional or global dynamics and interaction models. Remote sensing of the vegetation as shown above offer a unique tool for these developments, providing the specification of the systems be adapted to each particular need.

2. Simultaneity with high spatial resolution acquisition

Beside the thematic nature of the mission as described above, one key feature of the system is that it should allow simultaneity between high spatial resolution and the Vegetation acquisition. This condition is important for the development and validation of models : as it is usually done, study or pilot sites are chosen for specific experiment, on which data related to the model that is to be developed or validated are collected. It is expected that the Vegetation-HRVIR system on board SPOT 4 will provide high spatial resolution but low temporal frequency together with low spatial resolution but high frequency acquisitions, especially for local or regional studies, allowing some "zooming" capability that is essential for the extrapolation or integration of processes at different scales : this should provide a unique capability for multiscale experiments, especially if they are complemented with ground and airborne acquisitions. This capability does not have to be systematic : a typical experimentation could need for example 4 or 5 high spatial resolution acquisitions during one vegetation cycle for a better determination of surface parameters and overall, identification of land cover and/or land use. Simultaneity is most important, especially because of disturbances due to the atmospheric conditions —either clouds or aerosol contents that are highly variable— and to reflectance variability due to directional effects related to sun azimuth and elevation angles. Coincidence between measurements will allow precise adjustments that are not possible with existing systems (midmorning high spatial resolution —Landsat TM or SPOT— and afternoon high frequency —NOAA/AVHRR—). The combination of spatial resolutions will be discussed later.

3. Operational constraints for the main mission.

The typical uses described above all require long term monitoring, either for operational systems dedicated to weather forecast or agricultural production monitoring, or for scientific studies that require long time series for comparisons of several years and detection of regional or global changes. It should then be considered that the system must have a life time that should be not less than at least a decade, with possible changes in its characteristics that would ensure the continuity between successive instruments.

At shorter time scales, some days might be missed in some regions (for example in the winter season) because variations in vegetation covers are sometimes slow. However best efforts should be made so that data be available at a steady rate along the year, with no interruption in data availability that would be more than some days (to be refined depending of the time in the year and geographical location).

For the three typical uses described above, the following modes of operation of the system can be defined :

- for local studies, either in the context of modeling experiments or monitoring of special zones for example for agricultural or pastoral productions assessment, it is useful to have the capability to acquire the "Vegetation" data from local receiving stations that could provide better near real time access to raw data and possibly to adapted products,
- for other applications, when some entities have to monitor remote regions for which simple connections that would allow rapid transmission of locally received data cannot exist, it is desired to provide access to these data through a central archive. This particular capability will obviously need onboard recording and some capacity of high rate transmission and reception of telemetry. These facilities will have to be operated with the agreement of the system leading entities, as this operation mode requires some interaction with the satellite and particular transmission subsystems. Technical constraints and cost are the only limits to the number of facilities, no specification other than the need of that particular operation mode will be expressed.
- for the scientific applications related to global studies, the centralised archive is also necessary and a minimum number of receiving facilities adapted to reception of recorded data will have to be established to optimise the required volume of data that should be recorded onboard.

To perform these operation modes, it is likely that the system should be designed to provide

- a global mission for which a centralised archive would provide access of "Vegetation" data through a limited number of contacts,
- and a regional mission, for which users would get their data either through local receiving stations if their area of interest is located in the visibility circle of that station or through the centralised archive.

Besides the need for this type of operation, the system should be designed to allow "small" receiving stations to be operated by local entities. Some continuity with the existing scheme (AVHRR receiving stations) should be provided.

4. Background for specifications

The basis to determine the specifications is the existing knowledge of interpretation models as well as of correction of disturbing effects (atmosphere or directional effects). This knowledge was mostly obtained from studies using either ground investigations of radiometric properties of vegetation or soils, high spatial resolution satellites or NOAA-AVHRR data. Many references can be found in the literature (see for example refs. 12 and 13). It should also be taken into account that research activities will lead, before "Vegetation" launch date, to new methods that will probably allow to better correct for atmospheric effects or to include directional effects into interpretation models. But the strategy for defining the specifications must always be to design a system for operational use of satellite measurements into scientific or applicative projects and not for the development of new observation methodologies (improved atmospheric or directional effects corrections for example or new spectral bands for characterisation of other canopy parameters).

C. SECONDARY MISSION

As presented in Ref. 13, a secondary mission can be defined on observation of snow and ice. However, this secondary mission does not impose any other specification than those which are expressed for the main mission, except that ranges in reflectances should be extended for reflectances of up to 1.0 in the red and NIR bands if other specifications on radiometric resolution can still be obtained.

As areas covered by snow and ice on a large extent are generally near the poles, the conditions on sun zenith angle will not be always satisfied, then quality might be degraded on these areas.

Data collection should not be modified to record images related to that secondary mission on board, only local receiving stations would have to be used if necessary.

III. SPECIFICATIONS

A. FEATURES TO BE SPECIFIED

The main features that have to be defined for each typical use of the "Vegetation" mission are :

- the spectral properties : spectral bands , their location and bandwidth.
- the radiometric properties : resolution (expressed in terms of Noise Equivalent Difference of Reflectance : $NE\Delta\rho$) and accuracy (related to calibration capabilities)
- the temporal properties : frequency of data useful for a particular use, time and frequency of data acquisition,
- the geometric properties : spatial resolution, spatial coverage, viewing angles, accuracies for location and registration (between different bands, between different images)
- the coherence with high spatial resolution data,
- particular constraints on delivery, processing systems...

Application of the specifications :

As ancillary data could be used to improve the quality of measurements done by the instruments, some level of product must be defined : the following specifications apply to the first level of data that will be made available to users (Ref. 19). For this level, both system and ancillary informations are used to determine correction parameters. They include any knowledge that can be obtained from satellite sensors (attitude, orbit for example), from internal calibration systems as well as from calibration procedure that should be performed by the satellite operator. They also include informations that would be obtained from external data, especially for geometric processing where maps, digital elevation models or a database of ground control points could be used.

However, due to the lack of accuracy of some ancillary informations, the specifications might be difficult to meet or the quality of the data difficult to assess. This is particularly true for atmospheric corrections where the uncertainties on atmospheric properties might lead to uncertainies on ground reflectances that will be larger than the specifications. In that case, the quality will be expressed on the ground reflectance as specified but making the assumption that actual atmospheric effects are those which are computed using the atmospheric corrections procedure.

B. PROPOSED SPECIFICATIONS

1. The spectral properties

For each of the main missions, some specific parameters are important and have to be derived from remote sensing data. To keep the measurements as robust as possible, only wide spectral band measurements (≈ 50 nm) are considered and the objectives are to characterise the main features of plant canopies : absorption by chlorophyll, water contents and structural properties. The best and minimal set of spectral bands known to fulfil this need is composed of (see for example ref. 8)

- a red band centered on the absorption peak of the chlorophyll (0.665 µm),
- a near infrared band corresponding to the maximum vegetation spectral reflectance and principally related to the structural properties of the canopies and to percentage of soil covered by vegetation,
- a short wave infrared band centered around 1.65 µm where reflectance is related to water content of the canopy components and to its structure.

Considerations for atmospheric effects characterisation or correction should be added : among different possibilities that are under validation, both the use of adapted vegetation indices computed from red and near infrared reflectances (for example see ref. 18) and direct or indirect use of additional spectral bands in the blue region (see ref. 14) have to be retained. To provide capabilities of computing or characterising the atmospheric state (aerosols) an additional band can be proposed :

- a blue band (between .45 and .50 µm) where ground reflectance of vegetation cover is minimal and atmospheric aerosol diffusion effects are maximal.

The influence of atmospheric water vapour, which is most important in a wide near infrared band, can be severely decreased by limiting the upper portion of the near infrared band to avoid the .935 µm water vapour absorption band.

The spectral responses, as presented in annex A, will have to be as "similar" as possible to the high resolution instrument bands, at least for spectral bands that participate to the same mission : the red, near infrared and short wave infrared bands.

2. The radiometric properties

Radiometric properties must be described in terms of :

- radiometric resolution which gives the smallest radiance or reflectance which should be detected : it will be expressed in terms of Noise Equivalent Difference of Reflectance (NE$\Delta\rho$) that should be detected within specified ranges of solar elevation angles and reflectances for each spectral bands,

- radiometric calibration : to insure that measurements taken in the same image, in different spectral bands or at different times are consistent. This will be specified in terms of

  1. intra-image consistency which could also be specified as an equivalent to a radiometric noise. Variations of calibration within short range (about 10x10km corresponding to the elementary zones) can be considered as high frequency radiometric noise and will be specified as part of the radiometric resolution. Low frequency variations of calibration could be specified either as radiometric noise (specifying values of NE$\Delta\rho$ for large areas and for the entire image) or as intra-image calibration,
  2. inter-band calibration accuracy and
  3. multitemporal calibration accuracy.

  Estimation of radiances or reflectances should also be comparable with other instruments : this should be insured by the absolute calibration accuracy.

Notes :

1. *Calibration accuracy figures will be given as relative accuracy of reflectances : $\Delta\rho/\rho$. For example, an absolute calibration accuracy of 10% means that a reflectance of 0.10 if known with an accuracy of .01.*
2. *As the final data that will be used are surface reflectances, the specifications must be given for surface reflectances. For the detailed specifications of the instrument itself, top of atmosphere (TOA) reflectances and radiances should be used. The transformation between surface and TOA reflectance or radiances can be performed using the 5S code (ref 10).*

Considering existing research work on the use of reflectance properties (Ref. 15) or derived indices (NDVI, SAVI, MSAVI, GEMI,...) and taking into account first optimisations done with system engineers, the following values can be proposed, for sun illuminations corresponding to a sun zenith angle of less than 60° :

- **ranges for surface reflectance** (allowing for saturation for some land covers as snow or bright soils in some conditions or spectral bands and for clouds) should be consistent with Ref. 3 :

  1. from 0.0 to 0.5 for the red band,
  2. from 0.0 to 0.7 for the NIR band and
  3. from 0.0 to 0.6 for the SWIR band.
  4. for the blue band, as it is only envisaged as an experimental band for possible corrections of atmospheric effects on soil and vegetation, typical values of surface reflectances on these two land covers are generally less than 0.5.

- **surface reflectance resolution** of the order of 0.001 to 0.003 should be an objective for the specification with some adjustments for the different bands :

  1. for the red band, as vegetation ground reflectances are low (generally less than 0.1) , a target specification of 0.001 for reflectances of up to 0.1 is desirable, at least for analysis on small blocks of pixels corresponding to areas of about 10x10km (see elementary zones in section II.B.1). The specified value for $NE\Delta\rho$ could increase linearly up to 0.003 for reflectances values of about 0.5.
  2. for the NIR and SWIR bands, reflectance differences of 0.003 must be detectable for the entire range of reflectances and either for small blocks or the entire image.
  3. for the blue band, as the variation of TOA reflectance for the extreme conditions of atmospheric conditions (from 5km to 23 km visibility) is about 0.035, differences of about 0.003 should be detectable.

Comment : from existing knowledge it can be assumed that, when atmospheric conditions and directional effects can be accurately estimated, variations of the surface NDVI values of about 0.03 can be related to variations of vegetation fraction cover, biomass or intercepted photosynthetically active radiation that are significant (refs 5, 12, 1). For conditions corresponding to the beginning of growth of vegetation, when red and NIR reflectances of 0.1 and 0.2 respectively can be encountered , this means that differences of about 0.0045 should be detected in the red and NIR bands. Taking into account the improvement that will occur in the interpretation schemes in the next three or four years, the above figures for noise specifications seems to be of the order of what should be useful for operational programmes using these types of data.

- **Intra-image consistency** : the calibration consistency within an entire image (large areas) should give a $NE\Delta\rho$ better than 0.005 for any reflectance value.
- **Calibration accuracy** should be comparable to the high resolution instrument specifications that are within a quality range consistent with existing studies and probable needs for the next ten years :

  1. interband and multitemporal calibration accuracy better than 3%,
  2. absolute accuracy better than 5%

- **Digitization** : digitization must be consistent with the radiometric resolution specification.

3. The time and frequency of data acquisition

It must be related to the evolution rate of the processes to be characterised, taking into account limitations due to observations from space in the solar energy domain, mainly atmospheric disturbances and cloud coverage. These two factors will force an over sampling in time so that accumulation of acquisitions and screening of cloudy measurements can lead to a "useful" acquisition frequency adapted for vegetation studies. The effect of these factors on acquisition reduction can only be known from statistics on cloud coverage and atmospheric optical thickness, which is varying during the day, with the season and with the geographical location.

To get a minimal cloud cover, the best acquisition time is midmorning as many of the sun synchronous satellite remote sensing systems devoted to land applications (Landsat, SPOT...).

Existing operational systems are delivering information on vegetation or meteorological conditions with a period ranging from 5 to 10 days. A mean interval between useful acquisitions to measure changes in vegetation growth can be considered to be about one week : high level products should then be generated to provide data with the usual frequency, the "Vegetation" system providing sufficient data to derive the final useful information. To achieve this goal, experience from existing systems shows that actual acquisition should be as much as possible with a frequency of one day, to ensure coverage of the entire land areas each day. Even with this strong constraint, cloud screening will, in some regions and for some periods in the year, significantly decrease the useful acquisition frequency (especially in the tropical regions during the rainy seasons). This is probably the greatest drawback of solar energy measurements and any possibility to keep to the one day interval should be reserved.

Frequency acquisition is strongly related to spatial resolution, number of pixels by line of image and field of view of the instrument. Consistent modifications of these parameters should be discussed with the users to provide the best compromise, current values for the specifications being the preferable combination that was accepted today.

4. The geometric properties

From an instrument point of view, geometric specifications should be expressed in terms of :

- sampling rate in two directions,
- Modulation Tranfer Function for the entire instrument (optical and electronic components),
- Field of view,
- accuracies of location and registration for each band relative to the others or to a reference image.

From the users' point of view, specifications of spatial resolution, sampling rate and accuracies will define the main user's characteristics of the system while other instrumental specifications will be adapted during the instrument design phase taking into account physical or technical constraints.

Spatial resolution and sampling

Two strategies can be used to define spatial resolution and sampling : either to consider the "Vegetation" instrument alone or to consider the association with the high spatial resolution instrument. A good number of criteria to make the choice of a particular spatial resolution have been defined (see for example ref. 6). Both the standard deviation of NDVI values at some particular dates and the standard deviation of time differences of NDVI on some selected sites were chosen and represented on the following figures (Figure 1 and Figure 2).

These two figures clearly show that the information content decreases as spatial resolution increases but that the decrease in information content from Landsat MSS resolution to a resolution of more than 200 m is much more important than between 200m and 1km. Then, if the first strategy is considered, for one instrument that cannot have high resolution , some information at resolutions of about 200m has to be acquired : this is the MODIS case. In the second strategy and to extrapolate from biophysical models that are only established on "homogeneous" land cover, it is preferable to request some capability for sampling studies using spatial resolutions better than the Landsat MSS resolution and allow some flexibility for the low resolution system. As shown on Figure 1, to keep appropriate information on "Richmond" like zones that are very similar to classical European landscape, it seems desirable to specify a spatial resolution of about 1 km : this is coherent with studies on the European countries done for the MARS project where the AVHRR 1km resolution supplemented by high resolution imagery (Landsat TM or SPOT) proved to be satisfactory, with some problems due to lower resolution obtained for off nadir AVHRR pixels (ref. 15).

Then the requirement for spatial resolution and sampling interval is that it should be about 1 km, with preference for systems that would allow as constant as possible resolution in the entire field of view. The same spatial resolution and sampling specifications apply to all spectral bands.

Spatial resolution is also related to the shape of the MTF of the instrument that should be as high as possible up to Nyquist frequency; specifications usually retained for other instruments should be the objective : the MTF value must be no less than 0.3 up to a frequency corresponding to half the sampling frequency.

The field of view would have to be such that the entire globe can be imaged once each day, especially providing adjacent swath at the Equator. However, that requirement might lead to some problems :

- a complex design would have to be made to keep the radiometric quality within the specifications due to the high deviation from optical axis,
- spatial resolution might dramatically decrease due to earth curvature,
- directional effects due to high zenith observation angles might prevent any useful measurement. (For example , with an altitude of 800 km, an off nadir angle of 50° gives a zenith angle of observation of about 60° that represents a

maximum angle for which directional effects are becoming much variable and difficult to handle).

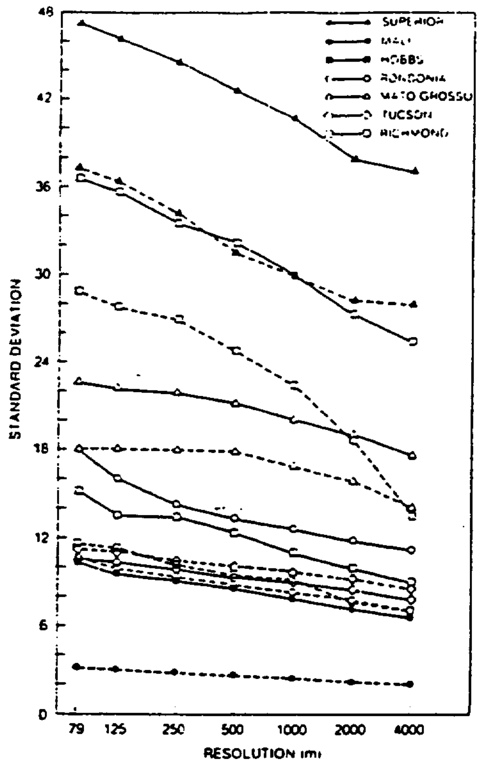

Figure 1: Standard deviation of NDVI on some selected sites for two different dates (solid and dotted lines) (from Ref. 6)

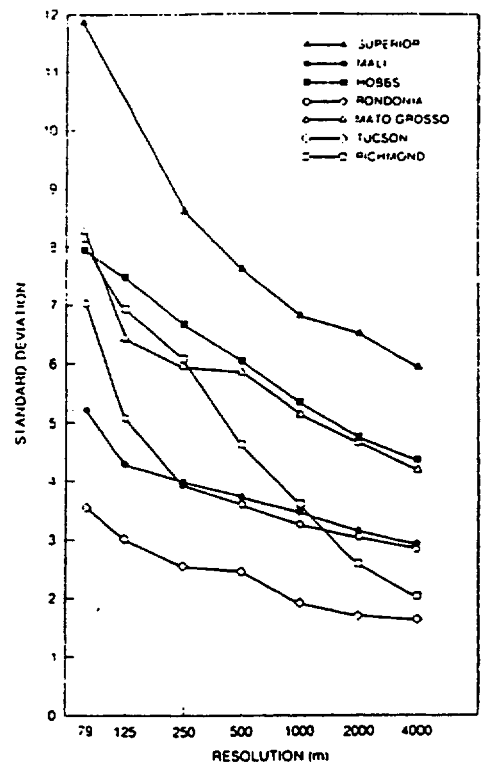

Figure 2: Standard deviation of differences between NDVI values at different dates for different spatial resolutions. (from Ref. 6)

Accuracies

Geometric quality must be expressed on the basis of the particular analyses that will be applied on the images : apart the local distorsion, some order of priority for specifications of the different accuracies can be given :

1. first, the highest priority should be put on the multispectral registration for spectral analyses or use of multispectral indices like the NDVI or new indices that could be generated using the SWIR or blue bands.
2. then comes the capability to correctly locate the High Resolution pixels acquired simultaneously, relatively to the VEGETATION pixels,
3. as the temporal evolution will be one of the most important feature analysed from the VEGETATION data, the multitemporal accuracy should be particularly good,
4. finally, the absolute location accuracy should allow adequate positionning of each time serie on other maps or geographical information.

Local distortion reflects the sampling accuracy within a small area and can be expressed as a quadratic mean of differences between the actual pixel position and a reference regular position. This characteristic should be consistent with the registration and multitemporal accuracies (see below) and such that the deviation for each spectral band be not more than 0.3 pixel,

Figure 3 represents the different types of errors that can be defined .

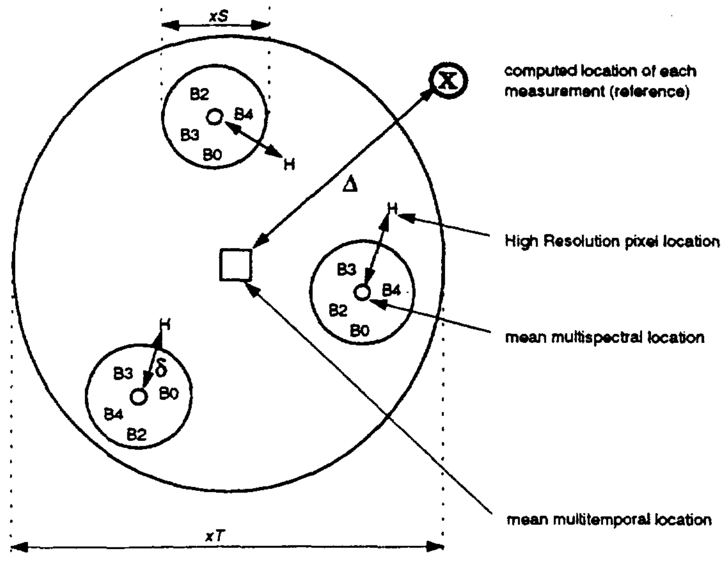

Figure 3: Diagram of errors to be considered for geometric specifications.

All measurements are represented by the position of their actual location relatively to the computed location represented by **X**.

Each individual spectral relative location for one date is represented by B0, B2, B3, B4 (blue, red, near infrared and short wave infrared spectral bands). The « mean multispectral relative location » is defined as the centre of the smallest circle including all spectral measurements relative locations. The multispectral registration error will be measured as the diameter of that circle : *xS*.

At one particular date, the corresponding High Resolution « multispectral pixel » will be located at H relatively to its computed location X. The colocation error is the distance between H and the mean multispectral relative location : δ.

At different dates, the mean multispectral relative locations will be located inside a smallest circle, the center of which is defined as the « mean multitemporal relative location ». The period that should be considered for the definition of that circle is one year. The multitemporal registration error will be measured as the diameter of that circle : *xT*.

Finally, the absolute location error will be defined as the distance between the mean multitemporal relative location and the computed location : Δ.

That particular scheme for definition of geometric errors puts a higher priority on the multitemporal registration than on absolute location of each multispectral pixel. However, the specification for the absolute location error of each multispectral measurement (one particular date) can be inferred from the specifications on *xT* and Δ.

The following specifications for the errors assume non biased errors and are given as the values of two standard deviations $\sigma_2()$ (corresponding approximately to a probability of 5% to have errors larger than the specified value in case of gaussian distribution) :

- multispectral registration specification : $\sigma_2(xS)$ should be significantly less than 0.3 km, with an objective value of 0.1 km,
- colocation specification : $\sigma_2(\delta)$ should be less than 0.3km,
- multitemporal registration : $\sigma_2(xT)$ should be less than 0.5 km with an objective value of 0.3km,
- absolute location specification : $\sigma_2(\Delta)$ should be less than 1 km with an objective value of 0.5 km.

For the blue band, as it should be used mostly for atmospheric corrections, at least for the first flight model of the instrument, the specifications for xS, δ, *xT*, and Δ can be relaxed to be of the order of 1km.

These specifications apply for the first level of products defined in the Product Definition document (Ref. 19).

5. Coherence with high spatial resolution data

As it is required that high spatial resolution data be used for specific studies together with the "Vegetation" data, some constraints have to be defined for the inter-instrument quality :

Collocation of pixels

See above.

Spectral bands consistency

The spectral bands of the two instruments should be as similar as possible, the relative difference between measurements on the same object being not more than 3%. This specification has to be insured on the typical spectral reflectance variations that can be found on bare soils and vegetation canopies.

6. Spatial coverage

Considering the importance of different areas of the globe both for scientific or applicative project, all the land areas should be imaged by the instrument at any time. Radiometric quality must be met as soon as the solar zenith angle is less than 60°. However, as described in the mission section, some areas could be excluded for the global mission : they are mainly areas covered by snow or ice (Antarctica and Greenland) for which the secondary mission could be performed using local receiving stations specifically installed for that purpose if there is no station dedicated to the vegetation mission itself.

To get daily coverage and then adjacent swath for the lowest possible latitudes, the system will be designed such that some overlap exist for high latitudes : geographical points at high latitudes might be imaged more than once a day but with different sun and viewing geometry. As this difference might give information on the directional properties of the surface, they should not be eliminated at any step of the acquisition-transmission-archiving chain.

7. Operation modes.

Central receiving system

The entire system should be designed to allow a centralised access to data over the entire globe. Users should find in a single facility :

- informations on all data acquired and processed to standard levels of processing, especially on their quality (cloud cover). Some information on High Resolution data acquired simultaneously to VEGETATION data should be made available.
- capability to process and deliver standard products,
- information related to the use of VEGETATION data sets.

See companion document on Products Specifications for a full description of the products (Ref. 19).

Local receiving stations

As described in the mission section, local receiving capacity should be possible with stations that are "affordable" to small organizations. Some continuity with the existing receiving stations should be provided, taking into account the new technical possibilities (changes in transmission bands, compression...).

As the quality of the data is strongly dependant from system informations on radiometry or geometry, these informations should be made available to the local stations for local processing up to the same data product as in the centralised archiving centre. It is also recommended that a standard preprocessing system be specified and provided for these stations.

Each local station will be responsible for other products processing and delivery as well as for their delivery time.

Degraded modes of operations

In case of failure of part of the system, every effort should be done to associate users through a structured entity similar to the International Users Committee and elaborate a new operating mode. Priorities should be established to provide as much compatible service as possible with the nominal mission. Some guidelines for priorities can already be given :

- the global coverage feature should be a high priority, leading for example to establish a network of local receiving stations in case of failure of one of the components of the system, allowing centralized access to the entire continental data set,
- data products similar to elaborate data sets already available from existing systems on the globe should be made avalaible, even if adaptability to particular needs cannot be achieved : for example synthetic data sets over periods of about a decade should be always available, possibly with only one sampling grid or on a predefined partition of the continents,
- the raw data, together with information on system parameters that should be used to process them, should **in any case** be archived because historical studies will have utmost importance for any analysis of changes at regional or global scales.

ANNEX A : SPECTRAL BANDS SPECIFICATIONS

The following figures give the minimum and maximum value required for the spectral response of each of the principal bands (red, NIR and SWIR) and for the experimental blue band.

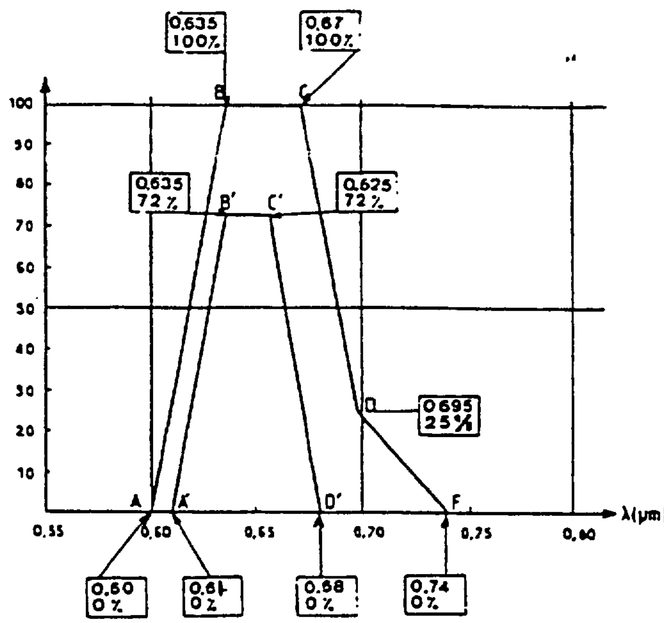

Figure 4: Red spectral response specification

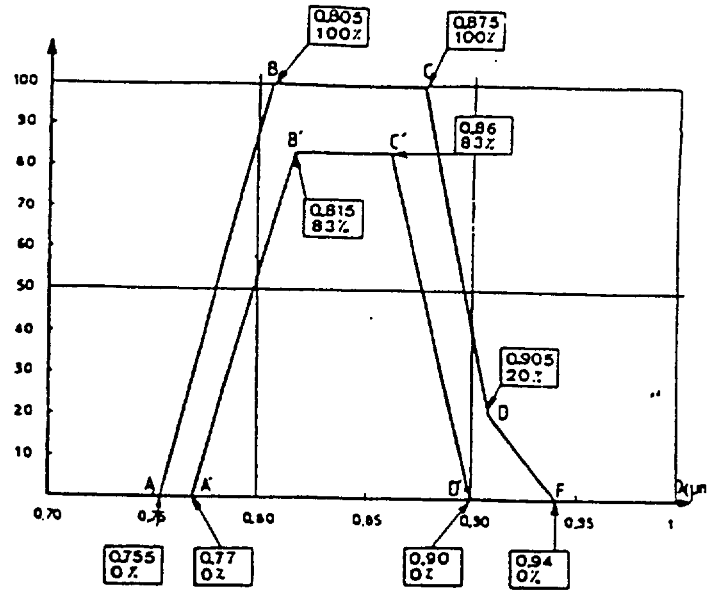

Figure 5 : NIR spectral response specification

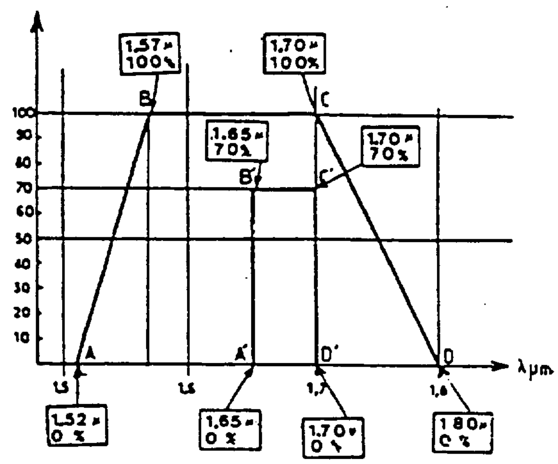

Figure 6 : SWIR spectral response specification

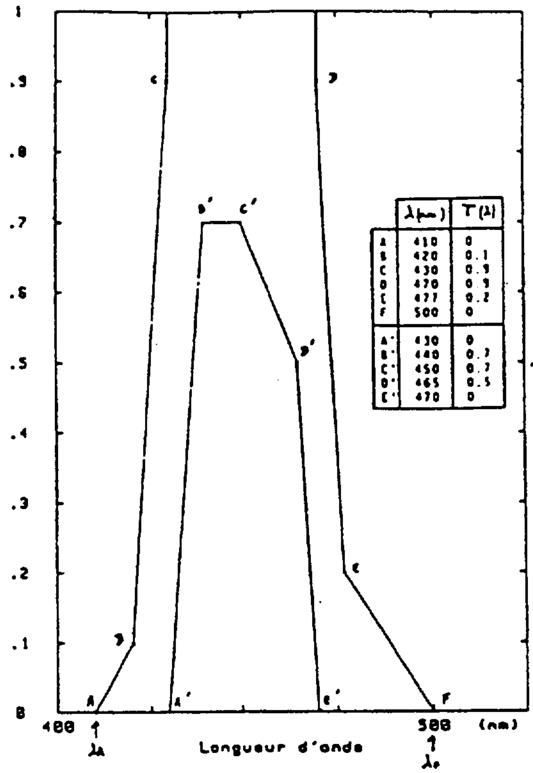

Figure 7 : Blue spectral response specification

Spectral bands		Wavelength	Range for surface reflectance
Operational :	RED	0.61 - 0.68 μm	0.0 - 0.5
	NIR	0.78-0.89 μm	0.0 - 0.7
	SWIR	1.58-1.75 μm	0.0 - 0.6
Experimental :			
	BLUE	0.43-0.47 μm	0.0 - 0.5

Radiometric resolution (NEΔρ)

RED	0.001 up to reflectances of 0.10
	linear increase up to 0.003 for reflectances of 0.5
NIR, SWIR	0.003 for the entire range
BLUE	0.003 for the entire range

Intra-image consistency : within an entire image, corresponding to a NEΔρ of 0.005 for any reflectance value

Calibration accuracy :

interband and multitemporal : better than 3%

absolute : better than 5% .

Table 3 : Radiometric specifications

Spatial resolution : in both directions 1 km at nadir (±20%), minimum variations for off-nadir observations,

Field of view : maximum off-nadir observation angle of about 50°

Accuracies :

local distortion :	less than 0.3 pixel,
multispectral registration :	significantly better than 0.3 km (0.1 km objective)
multitemporal registration :	better than 0.5 km (0.3 km objective)
location accuracy :	better than 500m desired, 1000m specified
registration with HRVIR :	better than 0.3 km

Table 4 : Geometric specifications

ANNEX C : SPOT 4 CHARACTERISTICS

Satellite

SPOT 4 is a sun-synchronous satellite in the series which began with SPOT 1 which was launched in february 1986.

Its main characteristics are the following :

Expected launch date : 1996-1997

Mission duration : 4 yrs

Weight : 2680 kg

Payload : 1470 kg

Energy : 2200 w (after 4 yrs)

Orbit Period 101.46 mn

Inclination 98.72°

Excentricity 1.3 10^{-3}

Number of revolutions per day 14 + 5/26

Cycle duration 26 days

Speed relative to ground 6.6 km/s

Equator crossing time (descending node) : 10:30 local solar time

	at the equator	at 45 ° latitudes
Distance between successive ground tracks[1]	2824 km	2000 km
Distance between adjacent ground tracks	108 km	76 km
Orbital altitude	822 km	832 km

Attitude control : pointing : < 0.15° (3σ)

rate : < 8 10^{-4} °/s (3σ)

[1] With a field of view of ± 50.5 °, the ground swath width of VEGETATION is 2200 km.

High Spatial resolution payload : HRVIR

Swath	60 km at nadir.
Depointing	up to 27° from nadir
Spatial resolution	20 m in multispectral mode
	10 m in "panchromatic" mode
Spectral bands :	
Multispectral mode :	0.50 - 0.59 µm
	0.61 - 0.68 µm
	0.79 - 0.89 µm
	1.58 - 1.75 µm
"Panchromatic mode"	0.61-0.68 µm

ANNEX D : LIST OF SUCCESSIVE MODIFICATIONS

From version 0 to version 1

(page references are for version 1 document)

Modifications result from note CNES S4.CR.36-1566-CN (11/17/92) :

B0 resolution should be 1km in the global mode :

1. modification to III.B.2 "surface reflectance resolution" section page 22 : no more reference to 1x1 or 4x4 km modes,
2. deletion of III.B.4 "Particular case for the blue band" section page 26.

Absolute calibration specified to 5% : modification of III.B.2 section "Calibration accuracy" page 22.

Multispectral registration : should be significantly better than 0.3 (page 26)

Coverage of all land surface areas : modifications to III.B.6 page 27.

From version 1 to version 2

A paragraph was added in the introduction to emphasize the need for evolution of the system (page 10)

a paragraph was moved from section III.A to section II.A and adapted to recall constraints and background which were taken into account for definition of the system. (page 13)

an annex was added to give a short description of SPOT 4 (annex C)

From version 2 to version 3

The modifications were recommanded by he System Concept Review (april 94) :

- the geometric specifications were reviewed to give a priority order between the different aspects of geometric accuracy,
- operation modes and degraded modes were reviewed
- product description refers entirely to the companion document

LIST OF ACRONYMS AND ABBREVIATIONS

5S	Simulation of the Satellite Signal in the Solar Spectrum : computer code for atmospheric effects on radiometric measurements (Ref. 10)
AVHRR	Advanced Very High Resolution Radiometer (one of the instruments on the low earth orbit meteorological satellites of NOAA)
CEC	Commission for the European Community
CNES	Centre National d'Etudes Spatiales (France)
EOS	Earth Observing System : US ensemble of platforms dedicated to the global change studies.
ESA	European Space Agency
EUMETSAT	European Meteorological Satellites agency
FOV	Field Of View for an observation instrument
GCM	General Circulation Model : model of atmospheric circulation for climate studies or weather forecast
GEMI	Global Environment Monitoring Index (Ref 18)
HRVIR	Haute Résolution Visible et Proche InfraRouge : high resolution visible and near infrared instrument on board SPOT 4 which is an evolution of the HRV (Haute Résolution Visible) instrument on board SPOT 1 to 3
IFOV	Instantaneous Field Of View
IGBP	International Geosphere Biosphere Program
METEOSAT	geostationary meteorological satellite operated par EUMETSAT
MODIS	Moderate Resolution Imaging Spectrometer : to be on board some of the EOS platforms
MSAVI	Modified SAVI
MSS	MultiSpectral Sensor : one of the instruments on board the Landsat satellites
MTF	Modulation Transfer Function
NDVI	Normalized Difference Vegetation Index : computed from NIR and VIS reflectances, ratio of their difference over their sum.
NE$\Delta\rho$	Noise Equivalent Difference of Reflectance
NIR	Near InfraRed domain (wavelength between 0.7 and 1.0 µm)
NOAA	National Oceanographic and Atmospheric Administration (USA)
SAVI	Soil Adapted vegetation Index
SWIR	Short Wave InfraRed domain (wavelength between 1.0 and 2.5 µm)

TM	Themapic Mapper : an instrument on board the Landsat satellites
TOA	Top Of Atmosphere : for reflectances or radiances
USDA	United States Department of Agriculture
VIS	Visible domain (wavelength between 0.4 and 0.7 µm)

REFERENCES

1. "Red and photographic infrared linear combinations for monitoring vegetation" C.J. Tucker, Rem. Sens. Env. 8, 127-150, (1979)

2. "Intercepted PAR estimated by spectral reflectance" J.L.Hatfield, G. Asrar, E.T. Kanemasu, Rem. Sens. Env. 14, 65-76, (1984)

3. "Spectral reflectances of natural targets for use in remote sensing studies" D.E. Bowker, R.E. Davis, D.L. Myrick, K. Stacy, W.T. Jones, NASA Refrernce Publication 1139 (1985)

4. "Comparison of North and South-American biomes from AVHRR observations" S.N. Goward, G.D. Dye, A. Kerber, V. Kalb, Geocarto, 1, 27-39 (1987)

5. "Vegetation spatial variability and its effect on vegetation indices" J.P. Ormsby, B.J. Choudhury, M. Owe, Int. J. Remote Sensing, 1987, Vol 8, Nà 9, 1301-1306

6. "Selecting the spatial resolution of satellite sensors required for the modelling of land transformations" J. Townshend, C. Justice Int. J. Remote Sens. 9:187–236 (1988)

7. "Profil spectral et estimation de la biomasse" F. Baret, G. Guyot, J.M. Teres, D. Rigal, 4ième Colloque International sur les Signatures Spectrales d'Objets en Télédétection, Aussois (France) ESA SP-287, 93-98 (1988)

8. "MODIS : advanced facility instrument for studies of the Earth as a system" V Salomonson, W Barnes, P Maymon, H Montgomery, H Ostrow in IEEE Trans. on Geoscience and Remote Sensing vol 27 n° 2 03/89

9. "L'évolution de l'environnement global – Rapport au Comité des Programmes Scientifiques du Centre National d'Etudes Spatiales" sept 89.

10. "Description of a computer code to simulate the satellite signal in the solar spectrum : 5S code" D. Tanré, C. Deroo, P. Duhaut, M. Herman, J.J. Morcrette, J. Perbos, P.Y. Deschamps, Int J. Remote Sensing, vol. 11, pp. 659-668, 1990

11. "Global Land Cover Classification by Remote Sensing : Present Capabilities and Future Possibilities" J. Townshend, C. Justice, W. Li, C. Gurney, J. McManus Remote Sens. Environ. 35:243–255 (1991)

12. "Review of the Workshop on the Use of satellite-Derived vegetation indices in Weather and Climate Prediction Model" G.G. Gutman Bull. Amer. Meteor. Soc. vol. 71, No. 10, October 1990

13. "A mission for global monitoring of the continental biosphere" F Achard, JP Malingreau, T Phulpin, G Saint, B Saugier, B Seguin, D Vidal-Madjar Jan 92, available at LERTS.

14. "Atmospherically Resistant Vegetation Index (ARVI) for EOS-MODIS" Y Kaufman, D Tanré in IEEE Trans. on Geoscience and Remote Sensing Vol 30 n°2 03/92

15. "Développement des actions visant à approfondir les possibilités d'application opérationnelle des satellites NOAA-AVHRR au suivi agroclimatique des cultures à l'échelle de la CEE" Contrat INRA-CCR n° 4223-9D-12 ED ISP F 04/92

16. "Improved Global Data for Land Applications" IGBP report n° 20, 92

17. "Requirements for terrestrial biospheric data for IGBP Core Projects" Toulouse Workshop June 17-19 1991. IGBP-DIS Working Paper #2 June 1992

18. "GEMI : a non linear index to monitor global vegetation from satellites" B Pinty, M Verstraete, to appear in Vegetatio

19."VEGETATION onboard SPOT 4 : Products Specifications" G. Saint VEGETATION International Users Committee 05/18/94