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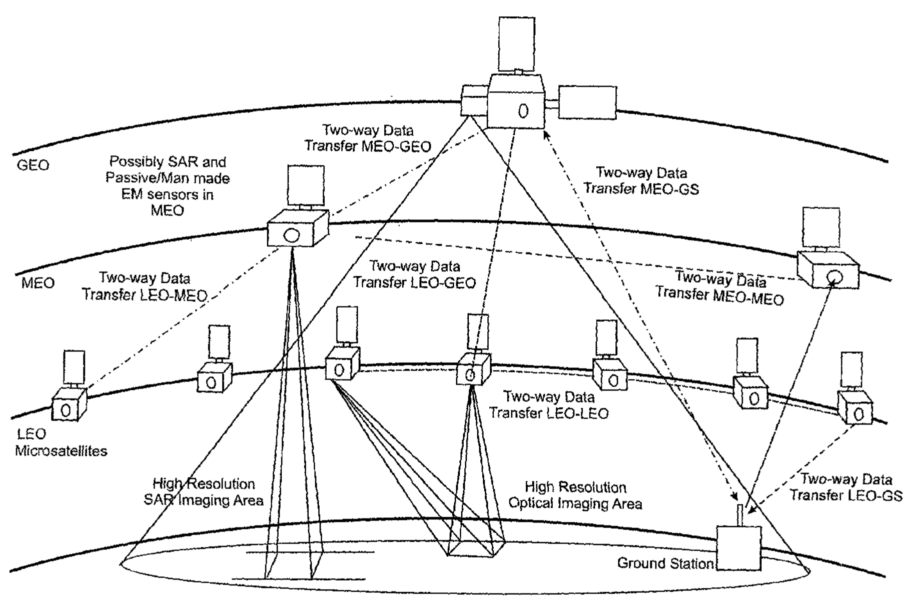
(54) **Title:** IMPROVED REAL OR NEAR REAL TIME EARTH IMAGING SYSTEM AND METHOD FOR PROVIDING IMAGING INFORMATION



(57) **Abstract:** A real time or near real time earth surface imaging system (11) including a large number of platforms (15) with one or more imaging sensors in non-geostationary orbits. The platforms are arranged in a constellar network (21) so that their footprints (23) are adjacently and overlappingly disposed with each adjacent platform. The footprints contiguously and concurrently cover a substantial part of the earth's surface (13) continuously and dynamically. A communication means (25) is also provided for conveying information between a user (14) requesting an image and the network of platforms.

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"Improved Real or Near Real Time Earth Imaging System and a Method for Providing Imaging Information"

Field of the Invention

The present invention relates to earth imaging systems and more particularly to earth satellite based imaging systems for producing images of the earth in real or near real-time and a method for providing such imaging information.

Throughout the specification, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

Background Art

The proceeding discussion of the background art is intended to facilitate an understanding of the present invention only. It should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was part of the common general knowledge in Australia as at the priority date of the application.

Imaging equipment located on board satellites has been used for producing images of, and data related to, the earth's surface.

However, these imaging systems are constrained by the stationary orbit, or the orbit path, of the satellites on which the imaging and data collection equipment is located. This means that only an image of, or data relating to, the earth's surface falling under the satellite's orbit can be obtained.

Further, where a satellite is in a non-stationary orbit, the areas of the earth surface falling under its orbit can only be imaged at certain time periods corresponding to when the satellite is aligned with these areas.

Current methods of satellite imaging require a number of steps to be undertaken by a user in order to operate and obtain an image. Firstly, the user needs to request an image of a certain area on earth, the satellite then needs to be positioned to obtain the image and acquire the image. The satellite usually then needs to be positioned for transmitting the image and transferring the image back to the ground station for processing. The user then receives the image after a predetermined time interval, which can be days old.

It is obvious that present systems and methods employed for satellite imaging under-utilise the satellite's ability and accessibility, even for strategic military applications. This results in images that may be days old, are restricted to certain users, and a cost per acquisition that is out of reach for the majority of the population. A lot of this time and cost is lost within the acquisition and processing of the images.

Although there has been much development of satellite technology, and in particular the production and installation of large constellar networks of satellites in low earth orbits (LEO) and medium earth orbits (MEO), this has been driven primarily by the commercial gains that are achievable with the use of satellites in the telecommunications sector. Accordingly, these large constellar satellite networks are virtually exclusively dedicated to private telecommunication networks and have had nothing to do with imaging.

Unfortunately, because the same commercial gains are not realisable in the imaging industry, imaging satellites are typically limited in number to 2 or 3 satellites in a network orbiting the earth, which makes it impossible for these networks to provide for instantaneous real time imaging on demand of selected parts of the earth's surface.

Another reason for the lack of development and implementation of imaging satellites in the private sector on a similar scale to the take up of satellite technology in the telecommunications industry is that of national security and the deployment of imaging satellites for military purposes.

The USA in particular has been sensitive to allowing private access to imaging satellites that can achieve images of the earth's surface having resolutions of less than 10 metres. However recently, relevant regulatory authorities in the USA have relaxed these requirements and have permitted image resolutions to be provided to the public down to 1 metre.

A further aspect of imaging satellites in current use is that the images and data are collected by expensive purpose-engineered sensors. These sensors generally do not use all of the available natural radiation from the earth to generate an image.

The earth's sun is believed to emit most of its energy in the so-called "optical" frequencies of the electromagnetic spectrum. The earth, by contrast, due to its lower non-incandescent temperature, is believed to emit most of its energy in frequencies that are non optical and which is of weaker strength.

Humans have evolved so that their brains process and recognise optical frequencies because the sun emits and the moon reflects strong levels of optical frequency electromagnetic radiation.

Some animals and insects "see" other radiation bands i.e. snakes, infra-red and bees, microwaves. A great deal of information about the earth has not been collected in these frequency ranges.

Disclosure of the Invention

It is an object of one aspect of the invention to provide for instantaneous real or near real time imaging on demand of selected parts of the earth's surface.

It is a preferred object of the present invention to supplement such real or near real time imaging to provide for images that include collected and converted radiation from a range of electromagnetic frequencies, including but extending beyond the optical range, into a form, that can be viewed by humans.

It is a further preferred object to provide for viewing a composite image of the earth's surface or a substantial portion of the earth's surface, in real time or near real time across a wide range of these frequencies.

It is another preferred object of the present invention to provide for improving the efficiency of the imaging process in real or near real time imaging on demand of selected parts of the earth's surface.

It is a further preferred object of the present invention to provide a virtual model of the earth gathered from real time or near real time images of the earth that is accessible to different classes of user for viewing purposes.

According to a first aspect of the present invention there is provided an imaging system for providing image information of a desired portion of the earth's surface to a user of the system in real or near real time comprising:-

(a) a large number of imaging platforms in non-geostationary earth orbits,

(i) each platform having one or more imaging sensors; and

(ii) the platforms being arranged in a constellar network so that the footprint coverage of the imaging sensors of each platform is adjacently and overlappingly disposed with respect to the footprints of each adjacent platform thereto, so that the footprints contiguously and concurrently cover a substantial part of the earth's surface continuously and dynamically; and

(b) communication means for conveying information between a user requesting an image of the desired portion of the earth covered by the footprints and the network of platforms providing same.

Preferably, the communication means includes:

(i) request delivery means to deliver a processed request for an image from the user to the platform(s) required to generate the image requested; and

(ii) image delivery means to deliver the image generated by the platform(s) to the user.

Preferably, the platforms form a constellation of satellites. Alternatively the invention may use aircraft such as high altitude balloons or unmanned remote controlled aircraft to locate said sensors above the earth for collecting said image data, or on any celestial bodies that provide line of sight viewing of the earth. The aircraft are preferably arranged so as to form a constellation.

Preferably, any portion of the earth's surface within the footprint coverage being capable of being imaged any time with a spatial resolution of approximately 1 metre or less and a temporal resolution of approximately 25 images per second or more.

Preferably, the imaging system includes an image request processing station including:

(a) an image requesting server to receive compiled requested information from the user;

(b) data processing means to generate processed image request data including:

(i) location processing means for determining the location and size of the portion to be viewed and the time duration of the imaging;

(ii) permission processing means to determine user access;

(iii) resource allocation means to determine requisite resources such as platforms and sensors to provide the image;

(iv) scheduling means to schedule the use of the resources amongst competing requests; and

(v) request data transport means to transport processed image request data via the request delivery means.

Preferably, the imaging system includes image data acquisition and processing means disposed on each platform including:

(a) data receiving means for receiving the processed request data;

(b) data processing means to process the received processed request data and to control the imaging sensors in accordance therewith;

(c) a data storage area to store data output from the imaging sensors;

(d) control and processing means to process the stored data to generate processed image data ready for transport; and

(e) image data transport means to transport processed image data via said image delivery means.

Preferably, the imaging system includes an image receipt processing station for processing received processed image data including:

(a) receiving means to receive and initially process the transported image data for decompression, decryption and the like;

(b) pre-processing means to calibrate, enhance and classify the initially processed image data if necessary;

(c) extracting means to extract the portion of the image originally selected by the user;

(d) transport processing means to process the extracted image data ready for delivery to the user; and

(e) transmission means to transmit the processed extracted image data to the user.

Preferably, the image receipt processing station includes combining means to combine the initially processed image data with other image data, possibly collected by other satellites, so as to produce a real-time or near real-time combined image of the selected area.

Preferably, the imaging system includes an earth imaging application means including:-

(a) a user request interface that is real-time interactive having:

(i) selection means to select a portion of the earth that is desired to be imaged by the user;

(ii) zooming means to fine tune the selection of the portion;

(iii) resolution means to select the desired resolution of the image;

(iv) frequency sampling means to select the desired sampling frequency of the image; and

(v) view formatting means to select the dimension in which the image is viewed and video or static views;

(b) compilation means for compiling requested information;

(c) transmission means to transmit requested information to the image requesting server; and

(d) a user image display interface integrated with the user request interface to display the requested image in real time or near real time, including:

(i) image processing means to process the received extracted image data from the image processing station for display; and

(ii) display means for displaying the processed image data to the user.

Preferably the image data comprises three-dimensional data of the earth's surface whereby the combined image is a three dimensional image.

Preferably, more than one sensor is provided on each platform to collect optical data. It is also preferable that at least one sensor on each platform is provided to detect and collect a number of frequencies beyond optical frequencies such as micro-wave, infra-red, ultra-violet or gamma radiation frequencies.

Preferably, said platforms are adapted so that image data of at least one area of the earth's surface is collected by at least two sensors at any one point in time whereby said platforms collect said three dimensional data.

Preferably said three dimensional data of an area is collected by a single sensor from two different points of an orbit of a platform containing said sensor. Preferably said sensor collects said data sets at a rate of 25 data sets per second or higher as the platform traverses its orbit path.

Preferably said platforms are further adapted to communicate with each other so that said image data of an area collected by at least two sensors is filtered by said platforms so that said combining means receives a selected set of image data of said area.

Preferably, the imaging system includes:

(a) data store means to continuously store and integrate image data from said image sensors to form a virtual model of the earth, said data being accessible for viewing desired portions of said virtual model;

(b) first communication means to deliver said image data continuously from said platforms to said data store means for storage and integration thereby; and

(c) second communication means for conveying information between a user requesting an image of the desired portion of said virtual model and the data store on demand.

Preferably, the first communication means includes a plurality of ground stations that receive the image information from the platforms and transfer the information to the data store means, and the data store means includes a central database for integrating and storing image data received from each of the ground stations.

Preferably, the central database is updated periodically from the ground station.

Preferably, a computer system accesses the central database and processes the images to create a virtual model of the earth.

Preferably, the virtual model is capable of being viewed in 2D and 3D.

Preferably, the virtual model of the earth is connected to a variety of gateways such that users may access the virtual model.

Preferably, the virtual model is capable of being degraded to provide a lower resolution image.

Preferably, the level of access depends upon the privilege rating of the user, certain users with high privilege ratings having access to the highest resolution images, while the lower resolution images are made available to users with lower privilege ratings.

Preferably, the communication means is adapted to inform the relevant platforms to transfer images of a higher order to the ground station and thus to the computer processor if a higher resolution or higher refresh rate is required by a user or plurality of users.

Preferably, the virtual world model is periodically archived.

Preferably, the imaging system includes a computer processor comprising various means to interact with the central database, means to interact with the user gateways and means to create a real time virtual model of the earth.

Preferably, the gateway comprises various means to interact with the user and the central computer to process user requests and provide the user with various image data output from the computer processor.

Preferably, the gateway interacts with the computer processor through networking means.

Preferably, the gateway uses the Internet to interact with the computer processor.

Preferably, images are acquired via the platforms on a continual basis over an area or footprint defined by the imaging hardware.

Preferably, the virtual model is updated according to user requirements through communication means with the platforms.

Preferably, at least one platform operates within the Lagrange points within the solar system.

Preferably, the imaging system includes communication platforms for transferring data from said imaging platforms to the earth to focus the imaging platforms capabilities towards increasing the effectiveness and efficiency of the system and rely upon the communication platforms for effecting high level communications with the earth.

Preferably, the communication platforms operate in a higher orbit to cover a number of imaging platforms and ground stations.

Preferably, the communication platforms operate within the Lagrange points. It is preferred that the earth-moon Lagrange points are used, and further preferred that the stable Lagrange points L4 and L5 are used.

According to a further aspect of the present invention there is provided an imaging system comprising a large constellation of platforms collectively having a first set of passive electromagnetic radiation sensors and a second set of active electromagnetic radiation sensor each sensor being adapted to collect data from the earth's surface; identification means for identifying an area on the earth's surface from where data has been collected by said passive sensor; comparison means for comparing said identified area with a target area; whereby in response to a positive result of said comparison, said active sensor is adapted to collect data from said identified area.

Preferably, said imaging system comprises a set of images of the earth's surface; said comparison means adapted to compare said data collected by said passive sensor with said set of images.

Preferably said second set of active sensors are wide range sensors.

Preferably, said sets of active sensors and said passive sensors are adapted to receive electromagnetic radiation from a spread of frequencies, such as optical, infra-red, ultra-violet and microwave frequencies; said set of image data derived from said spread of frequencies.

According to another aspect of the present invention there is provided a system for collecting data related to the earth; said system comprising a constellation of platforms some or all of which contain a set of sensors for detecting electromagnetic radiation emitted from the earth's surface; processing means for receiving at least two sets of data; each said set of data being received from a separate one of said platforms; and said processing means combining said at least two sets of data to generate a representation of the earth.

Preferably, said sensors operate to detect a pre-determined set of electro-magnetic radiation frequencies including optical, infra-red, ultra-violet and microwave frequencies whereby said representation is generated, at least in part, from data collected from electromagnetic frequencies outside the optical range of frequencies.

Preferably said unified representation comprises a graphical or visual representation of said data.

According to a further aspect of the present invention there is provided an imaging system for generating graphical representations of the earth comprising input means for receiving input data from a large constellation of platforms orbiting the earth; processing means for processing said data to generate a set of image data of the earth; and imaging means for generating graphical representations of the earth from said set of image data.

Preferably, the platforms are satellites.

Preferably, said input data comprises communications signals received by a constellation of communications satellites; and said processing means is adapted to process said communications signal to identify sets of image data of the earth.

Preferably, said constellation of communications satellites have a non-stationary orbit and collectively receive on a continuous basis communication signals from a predetermined area of the earth's surface, whereby said processing means updates said set of image data on a real or near real time basis.

Preferably, said set of image data comprises data in three dimensions.

Preferably, said imaging means access said data in three dimensions whereby said graphical representations are three-dimensional representations.

Alternatively, the data signals may be obtained from telecommunications receivers located in high altitude balloons, aircraft, including high altitude unmanned reconnaissance/communications aircraft.

Preferably, the set of image data comprises a virtual model of the earth.

In accordance with a further aspect of the present invention, there is provided a method for providing image information of a desired portion of the earth's surface to a user in substantially real time comprising:-

(a) imaging the earth from a plurality of platforms located above the earth's surface;

(b) arranging the platforms in a constellar network with the footprint coverage of the imaging that can be achieved from each platform adjacently and overlappingly disposed with respect to the footprint coverage of the imaging from each adjacent platform thereto so that the footprints contiguously and concurrently cover a substantial part of the earth's surface continuously and dynamically; and

(c) conveying information to a user requesting an image of the desired portion of the earth covered by the footprints and the network of platforms providing the imaging.

Preferably, the method includes spatially resolving the imaging of any portion of the earth's surface within the footprint coverage at any time to approximately 1 metre or less and temporally resolving the imaging to approximately 25 images per second or more.

Preferably, the conveying includes

(i) delivering a request for an image from the user to the platform(s) required to perform the imaging to generate the image requested; and

(ii) delivering the image generated by the platform(s) to the user.

Preferably, the method includes:

(a) conveying information from the network of platforms providing the imaging to a central data store;

(b) processing and integrating said information with previous data gathered to provide a virtual model of the earth; and

(c) making image data in respect of said virtual model accessible to various users via a gateway.

Brief Description of the Drawings

The invention will be better understood in the light of the following description of several specific modes for carrying out the invention. The description will be made with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of a constellation of satellites in accordance with the first mode;

Figure 2 is a representation of a typical set of footprints produced by a constellation of satellites such as Figure 1;

Figure 3 is a block diagram of an imaging system using the constellation of satellites of Figure 1;

Figure 4 is a flow chart of operation of the system in Figure 3;

Figures 5A and 5B are block diagrams of a compression system located on the satellites of Figure 1;

Figures 6A and 6B are block diagrams of two different configurations of a ground station and imaging station in Figure 3;

Figure 7 is a schematic representation of a combined optical and microwave sensor used in the satellites of Figure 1.

Figure 8a is a representation of bands of frequencies in the radio spectrum;

Figure 8b is a representation of bands of frequencies in the micro-wave spectrum;

Figure 9 is a transmission diagram of the earth's atmosphere;

Figure 10 is a table of frequencies allocated to passive sensor applications;

Figure 11 is a table of frequencies allocated to remote sensing applications;

Figure 12 is a further representation of the electromagnetic spectrum showing bands of natural phenomenon;

Figure 13 is a top level flow chart of the imaging system in accordance with the second specific mode;

Figure 14 is a top level schematic for the imaging system of the second mode;

Figure 15 is a flow chart showing the procedure for a user making an imaging request in accordance with the second mode;

Figure 16 is a schematic showing the ground segment of the second mode;

Figure 17 is a flow chart showing the procedure for processing a user request in accordance with the second mode;

Figure 18 is a laser communications system developed by Matra – Marconi Space;

Figure 19 is a schematic drawing of intra- (vertical) and inter-plane (horizontal) link arrangements in a satellite constellation;

Figure 20 is a schematic of network links in the Teledesic constellation;

Figure 21 is an example of a networking configuration for the imaging system of the second mode;

Figure 22 is a schematic of the use of a satellite in a different orbit to relay an image date from a LEO imaging satellite to earth;

Figure 23 is a flow chart showing the procedure for the real time uplink of data in accordance with the second mode;

Figure 24 is a flow chart showing the procedure for the real time downlink of data in accordance with the second mode;

Figure 25 is a flow chart showing the procedure for image acquisition in accordance with the second mode;

Figure 26 is a flow chart showing the image processing procedure in accordance with the second mode;

Figure 27 is a flow chart showing the procedure for image display in accordance with the second mode;

Figure 28 is a diagram showing how a single polar orbiting satellite images the earth's surface;

Figure 29 is a footprint on the earth's surface, projected from an imaging satellite, whereby the satellite has a single moveable sensor and therefore can image any area within the circular region;

Figure 30 is a geometry for calculating the footprint area;

Figure 31 are schematic projections of imaging satellite footprints on the earth's surface in which the white circles show the actual sensor beams and the shaded circles show the area able to be imaged by the sensor; and wherein:

Figure 31a shows the situation where the individual satellite footprints do not overlap;

whilst Figure 31b shows the case of minimum overlap for total coverage where the grey sensor beam is an example of a region being imaged by two satellites simultaneously, allowing tor instantaneous stereo image;

Figure 32 is a block diagram of an imaging system using the constellation of satellites of Figure 1, but in accordance with the third mode of the invention;

Figure 33 is a flow chart of operation of the system in Figure 32;

Figure 34 is a block diagram showing the structure of a ground station and imaging station according to the third mode;

Figure 35A is a block diagram showing the steps involved with a user accessing the virtual model of the earth;

Figure 35B is a block diagram showing the steps involved with the computer processing a request for access to the virtual model pursuant to Figure 35A;

Figure 36 is a top-level schematic block diagram of the imaging process in the remote control mode in accordance with the fourth mode of the invention; and

Figures 37A to 37B are flow charts showing the method of operation of imaging system in response to a user request; wherein

Figure 37A shows the steps involved with a user making the request through the gateway;

Figure 37B shows the steps involved with the computer processor receiving and processing the request;

Figure 37C shows the steps involved with a ground station sending the request to a satellite and the satellite processing the request; and

Figure 37D shows how the image data is received by a ground station and processed by the computer processor for ultimate delivery to the user requesting same.

Best Mode(s) for Carrying Out the Invention

Throughout the description of the different modes for carrying out the invention, the same reference numerals will be used to identify corresponding features of the system that are common between modes.

The first mode is directed towards an imaging system adapted to produce images of the earth, in near real-time.

In describing the first mode, reference will be made to figures 1 to 12 of the drawings.

From a user's point of view the imaging system operates through use of a computing device connected to a network, such as the Internet or a direct subscriber network such as a news organisation or government entity.

In operation, the user activates an earth imaging application which displays a map or image of the earth. The user selects a region of the earth that they are interested in. The user then zooms into this region so as to make a further selection in respect of an area of specific interest. Upon selecting the area of interest and identifying the resolution that they require, the user is presented with several options such as whether they wish to view a two dimensional image of the selected area, a 3 Dimensional (3D) image of the selected area, a video image in real or near real-time.

Rather than an image generated from purely optical data, a graphical representation of the earth can alternatively be presented that is generated from information obtained from electromagnetic frequencies other than optical frequencies. For example, information from frequencies in the ultra-violet, infra-red or micro-wave ranges may be used in generating a graphical representation of the earth.

To generate a three dimensional representation of a selected region of the earth, at least two separate data sources each having a different aspect to the selected region is required. A three dimensional representation may be a data set having spatial information on the selected region. This data set of spatial information enables a view of the region to be represented on a two dimensional screen. The spatial information enables the region to be viewed from a number of different angles. It also enables a user to navigate the region as the spatial information enables a continuous set of such two dimensional images to be generated.

Navigation of a region is seen as the display of a series of these two dimensional images. Each new image is from a new perspective/angle of the region that is slightly different to the previous angle/perspective. The change in perspective accords with the direction of navigation through the region and the speed with which the region is navigated. This provides the perception that the user is moving through a three dimensional space.

Images displayed to the user of a selected area are in near real-time. Near real time means that the image viewed by the user may be displayed with a delay of from 10 to 15 seconds after the raw data has been collected and processed by an imaging system. The data is updated at a rate of approximately, or more than, 25 images per second as the satellite traverses its orbit path.

Referring now to Figure 1, and other figures as appropriate, a schematic representation of a constellation of satellites 22 used by the first mode is shown to provide image data from an imaging platform 15 thereon, in real-time or near real-time, to a user 14 of an imaging system 11.

A constellation of satellites is a group of satellites orbiting the earth that are networked to each other in a constellar network 21 so that the imaging platforms 15 thereon provide coverage of the earth's surface 13 that is greater than can be provided by the imaging platform 15 of a single satellite 22.

Such constellations typically comprise Low Earth Orbiting (LEO) satellites, though they may comprise Medium Earth Orbit (MEO) satellites and GEO-stationary satellites. A constellation may comprise a series of satellites from some or all of the various orbit categories.

The orbit paths 17 of satellites 22 in a constellation of satellites having a non-stationary orbit are typically arranged so that a pre-determined area on the earth's surface is continuously in sight of the imaging platform 15 of at least one satellite of the constellation at any one time. Similarly a constellation of GEO-stationary satellites is organised so that a pre-determined area of the earth is continuously in sight of the imaging platforms of the satellites in the constellation.

For example, global hand held mobile communications networks, such as the Iridium network http://www.iridium.com, use constellations of LEO satellites without imaging platforms to provide continuous telecommunications service to hand held communications terminals across a large proportion of the earth's surface.

The use of a constellation of LEO satellites is particularly advantageous in an imaging system as it allows high-resolution images to be obtained compared with satellites in Geo-Stationary orbit (GEO satellites). An alternate advantage is that lower cost sensing systems for imaging platforms, such as Charged Coupled Devices (CCDs) may be used in place of the high cost systems for imaging platforms used in GEO-stationary satellites.

The use of LEO satellites to form an earth imaging system will allow the earth to be imaged through passive sensing of electromagnetic radiation emitted from the earth's surface. The radiation may be both naturally occurring radiation or man made radiation. The lower attenuation of passively sensed signals by LEO satellites due to the shorter transmission path of these signals to the LEO satellites, compared with their transmission path to GEO satellites, will enable the signals to be detected and an image or representation of the earth, or a selected region of the earth to be imaged.

For example passive sensing from LEO satellites enables passive detection of man made electromagnetic signals such as telecommunication signals, radio signals, television signals and radar signals. These signals are emitted from the earth's surface or are reflected, scattered or faded from the earth's surface by buildings, cars, foliage, bodies of water etc. These reflected, scattered and faded signals represent noise in a received/detected telecommunications, radio, television, or radar signal. However, the reflected, scattered and faded signals contain information as to the object that they have been reflected off or scattered by or faded by. Processing of these reflected, scattered or faded signals produces information on these objects that enables graphical representations of the earth's surface to be compiled.

Other forms of noise in man made signals may also contain information on the earth as will naturally occurring radiation. All of these types of signal sources, including naturally occurring radiation, may be used to form an image or representation of the earth.

For example, the signals detected may be signals from cellular communications terminals. Signals from base stations of cellular telecommunications networks will be detected and processed as these signals originate from a source with a fixed location on the earth's surface.

Where a satellite has a non-stationary orbit, such reflected signals can be sensed from two or more points of the satellite's orbit path. This enables two or more sets of data on each point in the satellites footprint to be collected. This data may be used to generate a stereoscopic image, or three dimensional to generate a three dimensional image in respect of the areas covered by the footprint. The data sets will be off-set in time. This off-set will correspond with the time it takes the satellite to move from a first position where the first data set is collected to a second position in its orbit where a second data set is collected. Collecting data sets and processing these data sets at a rate of 25 data sets or images per second, or greater, should enable near real time images/representation at video frame rates to be generated and displayed to users.

Other embodiments of the present mode may process reflection and scattering and fading noise in telecommunications signals received by telecommunications satellites in order to produce such an image. Alternatively, such information received by base transceiver stations in cellular communications networks may also be used.

In the present mode sensors are located in satellites of a constellation and are used for collecting image data relating to the earth's surface, the earth's crust and atmosphere. The sensors operate over a discrete set of electromagnetic frequencies, such as micro-wave frequencies, infra-red frequencies, optical frequencies, ultra-violet frequencies and gamma radiation frequencies.

This data is relayed to one or more ground stations which process the data before forwarding selected sets of this data in accordance with user requests.

In order to relay data from each satellite to a ground station the satellites are adapted to communicate with each other by means analogous to a local area network (LAN) or similar network configuration. This communication is also used to notify each satellite of selected data that they are required to relay to a ground station.

In the embodiment of the present mode, the vast majority of the satellites, if not all of the satellites, are low earth orbiting satellites, such as those used for hand held satellite phones. These satellites have a low orbit and so are replaced every few years, allowing updating of imaging apparatus. The low altitude orbit of these satellites allows conventional imaging technology such as charged coupled devices (CCDs) to be used. Alternatively, higher resolution images can be achieved through use of standard equipment.

Referring now to Figure 2, a schematic representation of sensor footprints 23 of image sensors 19 located in a constellation of satellites is shown, such as the constellation of satellites in figure 1.

The footprints 23 indicate that most areas of land mass on the earth's surface do or will fall within the footprint of two or more satellites at any one point in time. This enables the system to collect two or more sources of data relating to particular areas on the earth's surface at the same time. Two or more sources of data enable data sets of three-dimensional data relating to these areas to be collected, or stereoscoping of the data.

Two or more data streams also enable the imaging system to select between different streams of image data for an area selected by an operator. This enables the system to selectively control the amount of data transmitted by any one satellite in the constellation. Where the satellites in the constellation have non-stationary orbits, overlapping sensor footprints do or will enable image data collection of selected areas to be handed off from one satellite to another.

Other embodiments may use aircraft instead of satellites. Such aircraft may include high altitude balloons, and unmanned remotely controlled aircraft. Such systems preferably utilise these aircraft in a similar manner to a constellation of satellites.

Referring now to Figure 3, a block diagram of an imaging system 11 according to the embodiment of the present mode is shown.

The system 11 comprises a ground station 300 that receives image data from the imaging platform 15 of a satellite receiver 320. The satellite receiver is in communication with a constellation of satellites 22 such as the constellation detailed in Figure 1. The constellation of satellites is represented by a single satellite 325.

The ground station 300 is in communication with one or more other ground stations that are in turn in communication with different satellites 22 in the constellation 325 within their respective spheres of operation, so that a network of ground stations is provided to receive data from all, or substantially all, of the satellites making up the constellation at any one time.

Each ground station 300 is in turn in communication with one or more imaging stations 330. A user 14 of the system 310 logs into the imaging station by means of a communications network, such as a public switched telephone network (PSTN) or the Internet 305 using a personal computer (PC) 310.

Each ground station 300 receives data from the satellites that it is in communication with. This data is processed by the ground station before it is forwarded to the imaging station 330. The imaging station 330 operates to combine the streams of data from the various ground stations 300 so that an image of various points on the earth's surface 13, preferably any point, can be viewed by a user 14 on their PC 310 in real-time or near real time.

The system has two levels of encryption for the image data. The first level of encryption applies to information transmitted between satellites 22 of the constellar network 21 and the ground station(s) 300, and the ground station(s) 300 and an imaging station 330. The second level of encryption is applied to image data transmitted between an imaging station 330 and a user 14. The use of encryption enables the image data to be transmitted over a public network such as the Internet 305 without the data being interpreted by un-authorised users. The two levels of encryption isolate end users 14 from data transmitted by a ground station 300 to an imaging station 330.

Referring now to Figure 4, a flow chart detailing a method by which the embodiment of the imaging system operates is shown. The process of obtaining a real-time or near real-time image of a point on the earth's surface commences at step 400 where a user 14 selects by means of an application running on a networked computing device 310, an area of the earth's surface 13 that the user wishes to view.

At step 405 the user's terminal transmits to the imaging station 330 request data that identifies the area that the user wishes to view, the resolution to which the area is to be viewed, and other information such as whether the image is to be a two dimensional image, a 3D image, a still image, or a video image. The image may be derived from data sets of three-dimensional information that is obtained from electromagnetic frequencies outside of the visible spectrum.

At step 410 the image station 330 identifies, from a database of reference images, reference image data that corresponds with the area identified by the user's terminal.

At step 415 this reference image data is compressed and then encrypted and at step 420 the encrypted reference data is transmitted to the satellites whose footprints traverse the area selected.

At step 425 the selected satellites receive the data and store it in a module referred to as a compression/comparison module. The data stored in the compression/comparison module has been decrypted and uncompressed.

At step 430 image data received by the satellite's sensors is compared with the reference data stored in the compression/comparison module. This comparison enables data relating to an area selected by a user to be extracted from the received data.

Having extracted the required data from the received data, the satellite proceeds, at step 435, to compress the extracted data. This may be achieved by subtracting the reference data from the received data so that only the difference between the two signals is transmitted. Other means of data compression may be used, however it is preferable that the compression technique be an intra-frame compression technique, such as a technique that transmits the difference between successive image frames.

Once the requested data has been compressed it is then encrypted before the data is transmitted, at step 440, to a ground station.

At step 445 the compressed data received by the ground station is decrypted and expanded before it is transmitted to the imaging station for combining with other received data, after which it is transmitted to the requesting user. The process then terminates at step 450.

To enable a satellite to image more than one area at a time, a paralleled computing structure is adopted. Such a structure enables the process of Figure 4 to be repeated in parallel for a number of selected areas.

Referring now to Figures 5A and 5B, block diagrams of an embodiment of the present mode that utilises a sensor system installed on the imaging platform of some or all of the satellites 22 in a constellation of satellites such as the constellation of satellites in figure 1, are shown. Figure 5A provides a general overview of the configuration of the sensing system whilst Figure 5B provides a more detailed view of the configuration.

The sensor system comprises a sensor 500 that detects electromagnetic radiation emitted from the earth's surface in a predetermined range of frequencies and polarisations such as micro-wave and infra-red radiation, visible radiation and ultra-violet and gamma radiation.

As shown in Figures 5A and 5B, the sensor 500 outputs its received data to a compression module 505 forming part of a compression/encryption stage 507. This data is output on a frame-by-frame basis at a rate of 25 frames per second. The compression module 505 also receives reference data from a data store 510 after being treated by a control/processing stage 512. The data store 510 also receives data from the sensor for use in compression of the data by a technique such as an intra-frame compression technique.

The compression module 505 operates to compress each frame of data received from the sensor in accordance with a compression algorithm. Once a frame of data is compressed, the compression module 505 forwards the frame to an encoder 515, which operates to encode each frame, the encoder also forming part of the compression/encryption stage 507. Once the frame has been encoded it is transmitted by a transmitter 520 to another satellite 22 from where it is transmitted to a ground station 300. Alternatively the satellite's orbit may enable it to transmit encoded frames directly to a ground station, if that ground station is within its sphere of communication at that time.

The onboard satellite sensor system also comprises a receiver 525 that is able to receive data, such as further control data either directly from a ground station 300 or from another satellite 22. This data is forwarded to a decoder and expander module 530 that forms part of a decompression/decryption stage 532. The decoder and expander module 530 operates to decode the received data and to expand the received data for use by a control module 535 and for storage in the data store 510.

The control module 535 receives expanded data from the decoder and expander module. The control module 535 operates to compare data received from the sensor 500 with reference data received from the decoder and expander module 530. This comparison enables the control module 535 to determine which portion of the data fed to the data store 510 from the sensor 500 corresponds with data received from the decoder and expander module 530.

Having determined which portion of the data received by the sensor 500 is required for transmission to a ground station, the control module 535 controls the extraction and compression processes performed by the compression module 505 on the data received by the sensor 500.

Referring now to Figures 6A and 6B, block diagrams of a ground station 300 and an imaging station 330 according to the embodiment of the present mode are detailed. These figures show two slightly different configurations that may be adopted for the ground station and imaging station arrangements.

Commencing firstly with the configuration shown in Figure 6A, compressed data transmitted by a satellite is received by receiver 605, which passes the received data onto a decoder 610. The decoder 610 under the operation of control module 615 decodes the received data before passing it onto a decompression module 620 and control module 615.

Control module 615 processes the data to detect the area on the earth's surface that has been transmitted by the satellite. Having determined this area the control module instructs the decompression module 620 to access reference data from the reference data store 625 that corresponds with the area imaged by the satellite. This reference data enables the decompression module 620 to perform the reverse process of the compression process performed onboard the satellite.

The expanded data is then passed to an image combining module 630 that operates to combine the decompressed image with other image data, possibly collected by other satellites, so as to produce a real-time or near real-time image of the selected area. The image is compressed by means of an image compression technique, such as enhanced compressed wavelet technique, and, is then transferred via a PSTN or Internet network using image transferring software, (such as Image Web Server available from earth Resource Mapping (ERM), www.ermapper.com), to an updating module 640 that is housed in an imaging station 330. The updating module 640 transfers the updated image to an image data store 645. The image data store is accessible by users of the system through a server 650 using image transferring software, such as IWS above.

In the alternative configuration shown in Figure 6B, the receiver 605 of the ground station 300 receives compressed data from a satellite and passes it through a decompression/decryption stage 655, whereby the expanded data is stored in a data storage area 660. This expanded data is then processed by an image formation module 665 to form an initial image, which is then compressed and encrypted via a compression/encryption stage 670 for transmitting via a PSTN or the Internet to the imaging station 330 where it may be further processed for the user requesting the same.

The imaging station 330 comprises a decompression/decryption stage 675 for expanding the compressed and encrypted image received from the ground station 300 and a data storage area 680 for storing the expanded image data. The expanded image data is then processed further by an image processing module 685 to improve the image before being compressed and encrypted via a compression/encryption stage 690 and delivered to the user via the server 650 and the Internet 635.

An alternate embodiment may operate to transfer decoded data directly from the decoder 610 to the updating module 640. The updating module may then perform the decompression and imaging combining function of the decompression module 620 and the image-combining module 630 respectively.

Advantageously, the processing of the data may be performed by high powered personal computers (PCs) and work stations such as those using Microsoft's™ Windows™ operating system or the UNIX™ and LINUX™ operating systems which also work on Sun Microsystems™ workstations.

Referring now to Figure 7, a schematic representation of an imaging platform 15 is shown according to the embodiment of the present mode comprising a combined passive and active sensor arrangement that combine together to form an imaging sensor module 19.

A passive sensor is used for passive remote sensing which is a process that records terrestrial and reflected extraterrestrial electromagnetic radiation. Active sensors are used for active remote sensing which is a process that generates electromagnetic radiation to illuminate the surface of the planet and to record a reflected portion of the transmitted signal.

The imaging platform 15 comprises three passive sensors, namely a lagging sensor 705, a central sensor 710 and a leading sensor 715. Adjacent each passive sensor is located an active sensor. These active sensors comprise a lagging sensor 720, a central sensor 735 and a leading sensor 740. Each active sensor comprises a transmitter 725 and a receiver 730. Multiple passive/active sensor arrangements may be required for sensing different frequencies of the electromagnetic radiation.

The transmitter 725 illuminates a preselected area of the earth's surface with electromagnetic radiation. The receiver 730 detects the radiation reflected by the earth's surface in the band of frequencies transmitted by the transmitter 725.

Each passive sensor comprises a bundle of wave-guides, such as optic fibres, which interface to a fixed focal length lens. This combination of lens and optic fibres forms a scanning head that scans areas of the earth's surface within the sensors footprint.

Each fibre of the optic fibres is linked to a sensor such as a charged coupled device (CCD). The CCD sensor may be located at a convenient point on the spacecraft. Advantageously, CCD sensors are lightweight and robust allowing them to be located on a satellite with relative ease. They are also relatively inexpensive.

In the present embodiment, each CCD has its own controller that enables it to compare image data collected by its optic fibres with the reference data received from the ground station.

The three passive sensors operate to provide stereo imaging of the earth's surface. Provision is made for selecting between the three sets of image data collected by the sensor 700 in order to produce a three-dimensional image of a selected area on the earth's surface.

The three active sensors 720, 735 and 740 respectively, also have their image data combined to form a three-dimensional image of the electromagnetic data received from the earth's surface.

In operating the active sensors, it is preferable that the passive sensors first identify the area of the earth's surface that is to be imaged by the active sensors. Once the passive sensors have identified the requested area, the active sensors are then directed towards the requested area, whereupon the transmitters 730 are operated to illuminate the selected area with electromagnetic radiation.

Within the system it is preferable that an adaptive process is used to perform comparisons of image data collected by the sensors with reference data received from a ground station. An example may be a system where an initial comparison is performed, based on wavelet parameters. Should the correlation of the wavelet parameters fall within predefined values then a more detailed comparison may be performed.

In producing a three-dimensional image, an alternate system collects two or more sets of image data from one or more satellites. These separate sets of image data are combined by the ground station to generate a three-dimensional image of a selected area.

The compression scheme used is a high-level compression scheme that is adapted to transmit an update of the reference image from the satellite to the ground station, rather than transmitting all of the data collected by the sensors.

Where data from two satellites is used to produce a three dimensional image, interfacing between these two satellites is provided in order to ensure that the combined images are compatible to produce a three-dimensional image. Similarly, where data from two or more satellites is combined to produce an image that extends across two footprints, interfacing between the two satellites is also required to ensure that the data can be combined efficiently.

In order to overcome problems of pitch, roll, yaw, and orbit variations of the satellite, the sensors on the satellite continually supply image data to a ground station or the imaging station at a low data rate. The ground station or imaging station, operate to geometrically and radiometrically correct the received data to remove cloud and other influences whereby an accurate image of the planet is maintained by an imaging station in near real time. Thus, in this arrangement, the compressed data transmitted by the satellites represents an update of the current vegetative and human activity on the earth's surface.

The comparison process between the received data and reference data is based on several factors such as: histograms in each received band; edge structures;

band ratios; textures; time; polarisations; power attenuation (active); and known cavities.

Other embodiments are provided that use satellites and/or aircraft with non-stationary orbits to collect three-dimensional data through use of a single sensor (whether active or passive). To collect such three-dimensional data, electromagnetic radiation from the same area on the earth's surface is sensed from two different points on the satellite's orbit. This provides two separate data sets on the one area that are recorded with different attitudes between the satellite and the area. The two sets of data on the one area with separate aspects enables three-dimensional data on the area to be produced.

In the present embodiment, telecommunications signals received by telecommunications satellites are also processed. The signals are processed to identify noise produced by objects that reflect transmitted signals. Processing this noise enables information relating to the reflecting objects to be obtained. Similar processing may be performed on signals received by base transceiver stations of cellular telecommunications systems.

Referring now to Figures 8a and 8b, representations of the radio and microwave spectrums respectively and the frequency bands over which various types of navigation, communication and radar systems operate, are shown. These are examples of man made radiation that can be detected and be used for generating a representation of the earth.

Figure 8a identifies the well known band designations of the radio spectrum as ULF, VLF, LF, MF, HF, VHF, UHF, SHF and EHF, and the different types of communication media that utilise these bands.

Figure 8b is a graphical representation of the microwave spectrum that extends between approximately 0.3 GHz and 100.0 GHz. The microwave spectrum is divided into a number of bands of frequencies identified by the letters P,L,S,C,X,K,Q,V and W. Various frequencies allocated to these bands are detailed in Figure 8b. Signals detected in these bands should correspond with transmitting devices of the systems detailed in Figure 8a.

Referring now to Figure 9, a graph of the transmission characteristics of electromagnetic radiation versus frequency in Giga Hertz is shown. The transmission axis represents the degree of attenuation caused by the earth's atmosphere on a one-way (ie passive) transmission of electromagnetic radiation emitted from the earth's surface and received by a satellite in space. This transmission diagram is measured under clear sky conditions.

The transmission diagram shows that water vapour in the earth's atmosphere absorbs electromagnetic radiation at two frequencies of approximately 22 GHz, and approximately 180 GHz. The diagram also represents that oxygen in the atmosphere absorbs electromagnetic radiation emitted from the earth at two frequencies of just under 60 GHz and at approximately 120 GHz.

The transmission diagram also demonstrates that, in general terms, higher frequency electromagnetic radiation is attenuated by the atmosphere to a greater degree than lower frequency electromagnetic radiation. It should be noted that the 100% transmission as defined on the vertical axis is the transmission of 1 GHz radiation through the earth's atmosphere.

The transmission diagram demonstrates that at certain frequencies the earth's atmosphere operates as a band stop filter. Frequencies outside of these bands may be detected by use of sensors on board satellites. By detecting frequencies close to these bands, data relating to the present composition of the earth's atmosphere may be collected. As the composition of the earth's atmosphere changes, the transmission properties of the earth's atmosphere should change. Other windows and band stop frequencies may occur at different frequencies as the composition of the atmosphere changes.

The transmission diagram also demonstrates that outside of these attenuating bands, the earth's atmosphere presents a number of natural windows, such as the window centred on 35 GHz, 90 GHz and 135 GHz, which provide local maxima in the atmosphere's transmission properties.

Through the use of these band stop filter frequencies, and these window frequencies in combination with a constellation of satellites, data representing a snap shot of the earth's surface and the earth's atmosphere, or at least a predetermined portion of the earth's atmosphere and the earth's surface may be collected and transmitted to a ground station for later processing.

The use of a constellation of satellites also enables two-dimensional and three-dimensional data to be collected. This data may also be collected in real-time or near real-time and may be presented as either two dimensional or three dimensional data at video frame rates of 25 frames per second. In this way live data relating to electromagnetic radiation emitted from the earth's surface may be detected.

Referring now to Figure 10, a table detailing frequency allocations for passive sensors is shown. The frequencies are represented in Giga Hertz and the data in the table is labelled according to the applications that are allowed to operate in the nominated frequency bands. For example, the band of frequencies between 0.404 and 0.406 GHz is labelled with an "a". This indicates that these bands of frequencies are reserved for radio astronomy and hence no transmission of electromagnetic radiation at these frequencies from the earth's surface is permitted. Those frequencies labelled with a "p" operate within a band of frequencies whose primary use is for applications that transmit electromagnetic radiation. Those frequencies labelled with an "s" are within a band of frequencies whose secondary use is for applications that transmit electromagnetic radiation.

Figure 11 details radar frequency allocations for active remote sensing applications in Giga Hertz. Active remote sensing is the use of electromagnetic radiation to illuminate a selected area on the earth's surface. Electromagnetic radiation reflected from this selected area due to this illumination is detected by a satellite performing the illumination. These systems are active systems in the sense that they transmit electromagnetic radiation.

The imaging system of the present embodiment utilises these and other frequency allocations to collect data relating to electromagnetic radiation emitted from the earth's surface that is outside of the visible spectrum of electromagnetic radiation. It is preferable that further frequencies such as those representing infra-red radiation, ultra violet radiation and gamma radiation are detected.

Referring now to Figure 12, a representation of the electromagnetic spectrum from a frequency of approximately 1 Hertz up to a frequency of 10^{22} Hertz is illustrated. The horizontal lines indicate the approximate sprectral ranges of various physical phenomena and practical applications. The spectrum details certain frequency bands such as infra-red radiation, ultra violet radiation, visible radiation, cosmic rays, microwaves, etc. Further information such as the frequency bands where "electron spin magnetism", "molecular rotation and vibration", and "molecular energy in atoms and molecules" occurs is also detailed.

Location of passive sensors onboard a satellite that is tuned to these various frequencies of naturally occurring radiation, enables data relating to these and other phenomena to be collected. As the data is collected by satellites within the satellite constellation of Figure 1, real-time or near real-time representations of these phenomena for most of the earth's surface and/or atmosphere can be collected at any one time. Such a composite representation enables behaviour of these phenomena at various points on the earth's surface and/or atmosphere to be observed and composed.

Similarly, radiation from communication systems is also used to collect data that enables a representation of the radiation emitted by communication systems on the earth, to be developed. Other naturally occurring sources of electromagnetic radiation are also detected and are used for generating an image/representation of the earth.

Transmissions from mobile phones and other satellite phones and the reflections of these transmissions off buildings and other objects on the earth's surface is detected by a sensor on a satellite. Collection of this data from mobile telephones and other telecommunication systems is also used to generate a data representation, that is a graphical representation, of the earth's surface or at least part of the earth's surface.

Advantageously, much of the radiation that emanates from the earth will pass through cloud and water vapour enabling it to be detected in the presence of cloud bands and other forms of meteorological phenomenon. These phenomena will also be detectable at night as they occur at frequencies outside of the visible spectrum.

Now describing a second mode, reference is made to figures 13 to 31.

The second mode is substantially similar to the first mode, being directed towards an imaging system comprising a large constellation of satellites that can image all, or some portion, of the earth's surface continuously and transfer this information to an end-user with minimal delay. A particular feature of the embodiment of the present mode is the production of 'movies' of user-selected portions of the earth. This can be achieved from continuous observation, and a sufficiently fast revisit period.

In the present embodiment, the real-time imaging system is sub-divided into two distinct sections. Firstly, an imaging portion which relates to how the information is acquired and secondly a non-imaging portion which relates to how the information is processed and transferred to the end-user. The requirements for the first section are large-area (preferably whole earth) high spatial resolution ($\approx\leq$1m) combined with high temporal resolution (preferably $\approx\geq$ 25 'images' per second to allow 'movies') and for the second section, very fast transfer and processing.

Current imaging satellite systems do not meet these requirements for several reasons. This is chiefly due to the very large number of satellites needed to achieve the high space and time resolution and also because imaging satellites can, at present, only transfer data when they are within range of a ground station.

The embodied method for meeting the requirements for good coverage and fast transfer combines a large number of satellites utilising optical and microwave sensors with a network of inter-satellite links. The first feature allows high spatial and temporal resolution under all lighting conditions while the second will allow transfer of data when a given satellite is not in range of any ground station. The image processing and associated support systems will be similar to existing satellite systems.

A top-level schematic of the imaging process is shown in figure 13. The process commences with the user requesting an image, this request is then processed to determine how the request is to be implemented and then the information is transferred to the imaging satellite. The satellite's sensors acquire the requested image, which is then transferred to ground and processed. Lastly, the image is displayed on a visual output device for the user.

The constellar network 21 of satellites 22 to implement this process is shown in figure 14 and comprises a combination of:

1. A large satellite constellation size, giving global coverage.

2. A variety of sensors on each satellite, giving high resolution under all conditions.

3. Inter-linking of the satellites, giving real-time image transfer.

The real-time aspect of the imaging system means that the user-request will be real-time interactive, in contrast to all other satellite imaging user-request interfaces that are presently known. These known interfaces have a similar 'preview' system but then deliver the requested image in non-real-time so that the user must wait until the image is received before making any further requests based on that image. In the present embodiment, since the images are displayed with no (or minimal) delay after the request it is possible for the user to interactively make requests based on the real-time images being displayed.

From a user's point of view, the system operates via a computing device connected to a network, such as the Internet or a direct subscriber network such as a news organisation or government entity. The connection, or communications link, may include land-lines, microwave links and fibre-optics. The system is secured against unauthorised usage by some suitable means such as a password requirement or the need for proprietary software. The procedure for the user request is shown in figure 15.

In operation, a user firstly logs in to the system station by means of a communications network, such as a public switched telephone network (PSTN) or the Internet or another method. The user next activates an earth imaging application, and selects a region of the Earth in which they are interested, which may include zooming in to refine the target area. Having selected the area of interest the user is, possibly, then presented with several options such as the required resolution, the frequencies to be sampled, e.g. optical, infrared or microwave, and a choice of view format, e.g. two- or three-dimensional images of the selected area or static or video images in real or near real-time. Finally, the user's terminal transmits the total request information to the imaging server by means of a communications network, such as a public switched telephone network (PSTN) or the Internet or another method.

In practice, the imaging system that the user logs in to has a number of functional elements that make up a notional ground station 300 as previously described. As shown in Figure 16, the imaging system 11 can actually be separated into:

(i) The ground station transmitters and receivers 111, which handle the transmission and reception of all data, both acquired image data and system control and state information.

(ii) The Telemetry, Tracking and Control (TT&C) centres 113 associated with the ground station, which generally perform lower level satellite control operations.

(iii) The Satellite Control Centre (SCC) 115, which handles the overall control of the satellite network and generally provides higher-level satellite control.

(iv) The Imaging Station 117, which provides the image processing and associated processing for the imaging system, as previously described.

Note that there are actually several ground stations with transmitters and receivers 111 and associated TT&C centres 113 all able to communicate with one another and with the imaging stations 117 and the SCC 115. For processing reasons and for scheduling it is advisable for the imaging stations 117 to be able to communicate with each other. For the case where a user has a dedicated ground station transmitter and receiver 111, this could also have an associated imaging station(s).

The flowchart for the request processing and scheduling process is shown in figure 17. When the user request is received by the imaging station it is initially processed to determine the location (i.e. latitude, longitude and area coverage) and time (i.e. start and finish times) required. This information is processed to determine whether the user has the right to access the image information requested. If the request is allowed, then the system determines what resources are required, in terms of satellites and sensors, and this information is then used for scheduling. Resource allocation is done by each imaging station, which would be in communication with other stations so as to determine the total requests at any one time. Alternatively the resource allocation could be done in some more centralised fashion. Scheduling/resource allocation would be performed using either existing scheduling software/methods or some other system.

To determine the resource requirements the system would first obtain the position of all satellites, throughout the duration of the request, which would be calculated from a knowledge of their orbital speeds and trajectories using orbital dynamical theory. From this, a subset of those satellites which would satisfy the user-request requirements could be determined. The system would also calculate when each individual satellite should begin and end image acquisition. From these satellites and their sensor specifications the system would then determine what sensor settings would be needed, this would include the sensor pointing directions and/or sensor selection, if there is more than one sensor on the satellite as is the preferred case. The system would then schedule the requested imaging task using the existing tasks, their resource requirements and assigned priorities, if appropriate.

In addition to the processing of request information the imaging system would preferably determine the optimal uplink and downlink transmission paths for the request information and captured image. This is done at a TT&C centre 113, which also determines any other satellite housekeeping information that may need to be transferred (uplinked) to the satellite. The routing requires a knowledge of the state of the network, in terms of available inter-satellite links (ISLs), existing network traffic, and the position of the satellites and ground stations for earth-satellite transfer. The availability of ISLs will depend on the physical link state and the position and orientation of the satellites for inter-orbital plane ISLs. The system determines, using standard network theory, the fastest route for request and other information to reach the satellite (here termed uplink), and the fastest path for image and other information to return, via the network, to ground (here termed downlink). The satellites also have some routing capabilities so that the data routing is done 'in transit'.

Once the total information to be transmitted has been obtained, including image acquisition, routing, satellite control information and image reference database information, it is then transmitted by the ground station. Some form of compression is used on the data to reduce the amount of information which must be transmitted.

Satellite to satellite communication is necessary to achieve a wide global coverage of the whole earth, or partial coverage, in as near to real time as possible.

The real-time data transfer component of the imaging satellite system is similar to the existing telecommunications network and has certain distinct elements. Firstly, there is the method for communicating between satellites, the physical layer, which is characterised by the physical transfer method used (e.g. laser or radio) and the means of implementing this. Secondly, there is the network layer, or linking scheme, used to route the data either up to the target imaging satellite (uplink) or back down from the imaging satellite to ground (downlink). In addition, there is also the protocol method used for the transmission of data across the links.

In the physical layer, inter–satellite links (ISLs) are provided. When transferring data between two satellites there are two methods that may be used, radio links or laser links. In the present embodiment the system uses laser links as these have higher capacity, are more concentrated and require less power than radio links. Proposed systems have capacities in the order of Gigabits per second. Also, due to the optical frequency of the laser, there is no possibility of interference with radio communications. The ISL system is small, light and consumes relatively little power.

A system using laser ISLs must provide a means for producing a laser beam, a method for integrating the image data with the laser carrier and a method for directing this beam towards another satellite. In addition to this, the system needs a method for receiving the laser signals from other satellites and relaying these to another satellite or to ground. An example of a system designed for the telecommunications satellite constellations is shown in figure 18.

The system includes a method of tracking the ISL beam from the imaging satellite to the data-relay satellite. A similar system to that used with the SILEX/SPOT4 system is used. In this method, the satellites 'search' for each other using a wide angle beam to roughly locate each other. Next, a finer beam is used to refine this pointing and finally, when the satellites are aligned, they 'lock-on' to each other and data-transfer begins. The ISL system therefore needs some method of directing the beam to allow for the relative motion of the sending and receiving satellites. This is either a movable mirror (as in figure 18) or an optical phased array, similar to the phased antenna arrays used in radio.

The other critical feature in the data transfer chain is the initial link between the ground station and the space-based network segment. This physical link is a microwave link similar to existing uplinks in communication systems. The attenuation of a microwave uplink is lower than optical links. In other embodiments it is possible to use some other link type, such as optical lasers, which have higher capacity.

In addition to the physical method of transferring data between satellites, it is necessary to have some method of routing the data via these satellites to earth. This will depend on the network between the satellites, i.e. how and in what fashion they are linked. Satellites in a constellation are generally arranged in several discrete orbits (or orbital planes) with multiple satellites in each orbit. Links can then be intra-plane or inter-plane. In the present embodiment both are used, as shown in figure 19. This sort of linking arrangement is used in telecommunications constellations, for instance the Teledesic™ network shown in figure 20. Within an orbital plane, satellites stay at fixed distances apart so it is simpler to link intra-plane rather than inter-plane where the satellites may move relative to each other.

There are several methods suitable for transferring image data from a constellation of satellites to a ground station. For simplicity of explanation, it is assumed that the system has only one ground reception station, however, in the preferred embodiment of the present mode, a multiplicity of ground stations are used.

There are a large number of configurations that allow real-time data transfer, due to the combination of imaging/non-imaging satellites used and the orbits which these satellites are in.

Possible network configurations for the ISL network are the following:

1. Imaging Satellite→Imaging Satellite→Ground

2. Imaging Satellite→Other Orbit→Ground

3. Imaging Satellite→Communications (non-imaging) Satellite→Ground

Possible orbits are:

1. GEO based satellites
2. MEO based satellites

These are shown in figure 21.

In the networking scheme adopted in the present embodiment, the imaging system has a data transfer path which goes between the imaging satellite and either directly to ground, if this is possible, or via one or more 'routing satellites' if direct ground contact cannot be achieved. These 'routing' satellites may or may not have imaging capabilities. Imaging capabilities are not necessary for the data transfer portion of the system, however, in the present embodiment, the 'routing' satellites also have an imaging capacity. The 'routing satellites' are GEO-, MEO- or LEO-based, depending upon the particular embodiment chosen.

With the intermediate satellites having imaging capabilities, there are two options. Firstly, all of the imaging satellites are purpose-built for the variety of sensors. This requires adequate resources and the communications and data-management network/infrastructure to support this. The system is also designed to minimise the time from the image request to the display of the image, by optimal use of the satellites and their communications capabilities. This gives maximum flexibility to the design of the overall system.

With the second option, all the satellites are from a third party design and the system's sensors are 'piggy-backed' onto them. An example of this would be to place the sensors onto Teledesic™'s proposed satellite constellation. One main advantage of using third-party satellites is that the communications infrastructure is already in place, thus reducing costs and time. However, since the third-party satellites are not specifically manufactured for the imaging system of the present embodiment, significant redesign of the third-party system may be necessary. For example, space on the platform would be needed to house the sensors, and the imaging system would need to be integrated into the existing one provided on the particular platform. This second issue may not be too difficult for a proposed ‘multi-media internet-in-the-sky’ system, like Teledesic™, as these are designed to handle image data as well as other forms of data, so the onboard switching would be tapped into and utilised. However, if an existing telecommunications constellation was to be used, the integration of the sensors with the on-board processors may prove to be more difficult, as these satellites only deal with speech data and not images or movies.

In one embodiment where the relay satellites do not have imaging capabilities, the relay satellites are in geostationary orbit, similar to the system planned for use with SPOT4 or in Medium Earth Orbit (MEO) or in LEO. The system operates in a similar fashion to that shown in figure 22.

Advantages of using geostationary relay satellites are their large area of coverage, hence only a few are needed, and their stationary position, relative to the earth’s surface which simplifies the ground reception.

In another embodiment, a network of MEO satellites, equipped with ISLs, are used in a similar manner to relay the image data back to earth. Using a network of MEO satellites has the advantage of requiring a smaller number than a LEO constellation and the satellites do not have to be designed for imaging but only for communications.

In a further embodiment still, using a LEO constellation for imaging, it is advantageous to design ‘routing’ satellites with no imaging capabilities.

Another scheme using ‘non-imaging’ routing satellites in a further embodiment is to relay the image data from the sensing satellites to ground via a separate constellation/network of communications satellites. These satellites are distinguished from the ‘imaging’ relay satellites described above by being separate to the imaging system. For example, the satellites are from the Teledesic™ system or some other external provider. Advantages of using third-party relay satellites are their large area of coverage and inter-satellite links

(ISLs), which are important for providing 'real-time' ground reception. Additionally, by not being a direct part of the imaging system, the development and maintenance of the transfer-to-earth portion of the system is simplified.

In addition to providing the actual network linking, particular communication protocols are used for transferring data along the links. For both the ground–satellite and inter–satellite links, a system specification for the data format is made to allow optimal data transfer rates. The data transfer protocol has provision for error-checking.

An advantage of using satellites within the system solely for communication purposes, in addition to decreasing the complexity of the imaging satellites, is that bandwidth can be controlled and optimised to provide data faster.

Another embodiment of the invention involves using natural bodies within the imaging system as a base for transponders, for example the moon.

In all of the constellar network arrangements of the present embodiment, the satellites 22 operate within the Lagrange points, which are invisible points of balanced forces or librations, within the system. More particularly, the stable earth-moon Lagrange points of L4 and L5 are used. Operating the satellites within the Lagrange points allows for a constant reference point to be used with no external forces acting upon the satellite.

In addition, the communication means used between the various imaging platforms, especially between those outer imaging platforms for uplinking and downlinking transmissions, high bandwidth lengths are used, such as optical links with suitable encryption and compression means.

The method of operation for the real-time uplink used in the embodiment of the present mode is shown in figure 23. The procedure commences with the transfer of compressed and encrypted data from the ground station to a space-based network node (i.e. a satellite). This satellite examines the data to determine if it is the intended recipient of the information. If not, it determines which inter-satellite link to use for data transfer, either by examining the data for routing information or by performing some routing to determine the next optimal step in the data transfer chain.

When the ISL has been determined the satellite then attempts to establish the physical link to the intended satellite. Slightly different methods may be required depending on whether the link is intra- or inter-plane, however the general approach is as described above. Once the link is established, the data will be transferred using the designated communications protocol. Finally, the receiving satellite examines the data to determine if it is the intended recipient of the data and takes the appropriate action.

The overall method of operation for real-time downlinking used in the present embodiment is shown in figure 24. It commences with the transfer of compressed and encrypted data from the imaging satellite to the ground station, if this is possible, or to a space-based network node (i.e. a satellite). If direct transfer to ground is not possible, the satellite determines which ISL to transfer the data across, either by examining the data for routing information or by performing some routing to determine the next optimal step in the data transfer chain.

When the ISL has been determined, the satellite then attempts to establish the physical link to the intended satellite. Slightly different methods may be required depending on whether the link is intra- or inter-plane, however the general approach is as described above. Once the link has been established, the data is transferred using the designated communications protocol. Finally, the receiving satellite examines the data to determine if it can transmit to ground and takes the appropriate action.

The sensors used in the real time imaging system detect EM radiation emitted by the earth's surface over a range of frequencies such as microwave, infrared, visible, ultraviolet and gamma radiation. Since, at present, one single sensor cannot currently cover this wider frequency range, a generic sensor system only will be described. A notable exception to this is the case for active sensors that require a transmitter, in addition to the general embodiment of a passive sensor.

A particular feature of the image acquisition process in the present embodiment is the use of both optical and microwave sensors on the same satellite to allow all-weather day/night imaging capability.

The system comprises a data receiver that receives data, such as control instructions and reference data, either directly from a ground station or from another satellite. This data is processed, including decryption and de-compression, to determine what the satellite is required to do to perform the instructions. The sensor component outputs data to a data storage area (DSA) and to the control and processing module (CPM), which performs compression, encryption and other image processing such as geo-locating the image.

A large number of satellites are required to achieve a ground resolution of 1m or better and an update frequency of 25Hz. To solve this problem two methods are available.

In the present embodiment the method adopted uses sensors with independently directable beams which allow more area to be imaged, within an 'effective footprint', than with a single fixed beam. The system would have a multiplicity of sensors that are able to move in 2 dimensions to record data from a given target that lies in the satellite's effective footprint. This system, assuming a sufficient number of satellites, gives partial coverage with a fast refresh rate, or global coverage with a slower image refresh rate. This method is able to be implemented using radar sensors, with the beams being directed using steerable antennas. In addition, by using movable sensors, the effective footprints are made to be overlapping to allow stereo imaging.

In another embodiment, a method is adopted using a number of sensors, each imaging an area within the footprint through a static lens. This method has a large number of sensors on the satellite all observing different fixed areas within the footprint simultaneously. An example of such a system is an optical/IR passive sensor comprising a bundle of wave-guides, such as optical-, i.e. glass-, fibre, that interface to a fixed focal length lens. Each fibre in the fibre optic bundle is linked to a separate optical sensor such as a charged-coupled device (CCD), which is located at a convenient point on the spacecraft.

The processing scheme adopted in the present embodiment is shown in figure 25. The image acquisition process commences when the satellite receives the image request, and any other information, from the ground station. If the data has been compressed/encrypted, then it is de-compressed/de-encrypted and passed to the control and processing module (CPM). The CPM analyses the information and then instructs the sensor instruments in the necessary fashion to implement the request. This may include such things as the angle of sensor pointing or the particular sensors to utilise.

Data received by the satellite's sensors is sent to a data storage area (DSA), on a frame-by-frame basis, at a rate of ≥25 frames per second. Due to onboard memory constraints, it may be necessary to compress the data stored in the DSA. The sensed data is sent to the CPM for processing and/or compression. The system uses some form of compression to reduce the quantity of data that must be downlinked to the ground station. Downlink data may also be encrypted for security reasons.

An inter-frame compression technique is used, i.e. one that transmits the difference between successive image frames. This is achieved by a comparison between the current image and previous images, which are stored in the DSA. An adaptive process is used to perform this comparison. An example of this is where an initial comparison is performed, based on wavelet parameters. Should the correlation of the wavelet parameters fall within predefined values then a more detailed comparison is performed. The comparison process is also based on several factors such as, histograms in each received band, edge structures, band ratios and textures. Alternatively, other forms of image compression may be applied.

In the present embodiment, some, or all, of the 'image processing' is done on-board. This includes the processing required by synthetic-aperture radar techniques or image calibration. Additionally, the system also performs a comparison between the current image and geo-located reference data (i.e. data whose geographic location is known) to allow the user-selected area to be extracted from the sensed data. Extracting the requested data from the sensed data further reduces the volume of downlinked data. In other embodiments, some, or all, of the on-board processing is done on the ground so that the satellite essentially transmits raw data.

To enable a satellite to image more than one area at a time, a paralleled computing structure is adopted. Such a structure enables the above process to be repeated simultaneously for a number of areas within the same region. Finally, the system transmits the data to ground via the optimal data transfer route. In addition to the image data, other information such as satellite status, network and ISL status and satellite pointing direction is also downlinked.

The image-processing scheme of the present embodiment shown in figure 26, outlines the overall structure of the processing required to produce an image from raw sensor data. For simplicity, it will be assumed that all processing is done in the imaging station, however it is possible that both the satellites and the end user software will do a proportion of the image processing.

The imaging station receives data from a ground station and decompresses/decrypts the data. This data is then pre-processed, enhanced, and possibly classified, before the area selected by the user is extracted and then compressed/encrypted before finally being transmitted to the user.

Image pre-processing involves calibrating the image to remove any systematic errors, or offsets, that may have been introduced by the processing involved in converting synthetic-aperture radar data into an image. The calibration occurs in two main areas: geometric and radiometric calibration.

Geometric calibration corrects for the orientation or pointing of the satellite, relative to the fixed earth co-ordinates of latitude and longitude. This is done either by comparison with an archived geo-located reference image, or by a knowledge of the pointing vector of the satellite and the sensor which then allows appropriate transformations to be made to the image.

Radiometric calibration allows the relationship between the incident radiation intensity and the sensor output to be quantitatively determined. This is done by periodic comparison with an EM radiation source of known strength such as the sun or, for an active sensor system, against a target of known backscattering cross-section.

Image enhancement involves the removal of random errors, e.g. noise, from the image and additional processing to improve the image, such as incorporating stereoscopic effects. The system performs processes such as contrast modification, edge detection and noise reduction. If non-optical frequencies have been used then the system will use false colouring and overlays of multiple frequencies to form the image. Stereoscopic processes are also performed on the image to produce a three-dimensional effect. This includes a change in perspective transformation, to give a 'fly-through' effect.

After the image has been pre-processed and enhanced, image classification is performed. This is a technique which uses 'pattern recognition' to group the image information in ways that makes visual interpretation simpler, or more efficient, for the end-user. The human brain performs image classification automatically. For example rather than observing a random array of brightness and colours the brain recognises a region as being a dwelling, therefore classifying all the information in that region as 'house', as opposed to, say, 'vehicle'. An example of this type of image classification in an imaging system is a microwave image having radar backscatter being processed to identify friendly or hostile objects. In the present embodiment, this pattern recognition uses neural networks or some other process.

Once the image has been processed, the portion requested by the user is then extracted. This is usually done after the image processing as the techniques may require large image sizes for statistical purposes, however this may be done at an earlier stage to reduce the volume of data. Finally, the data is compressed/encrypted before being transmitted to the end-user's system.

In the present embodiment, the image display is handled differently than in many current user interfaces. These interfaces generally have a 'preview' system, similar to that in the user-request section of the present imaging system, but then dispatch the requested data in non-real time to the user. With the present system, there is no (or minimal) delay between the user-request and image display. In addition once the initial image has been obtained, continuous (refresh rate $\approx\geq$25Hz) imaging of the requested region is possible, which is a particular feature of the present embodiment.

From a user's point of view, the system operates via a computing device connected to a network, such as the Internet or a direct subscriber network such as a news organisation or government entity. The connection, or communications link, includes land-lines, microwave links and fibre-optics. The user's system receives the image data over the network from the imaging station and then performs some image processing on the data before displaying it in the requested format on an output device.

Some, or all, of the 'image processing' is done by the user display device. The level of data processing is tailored to the user's requirements and to capabilities of the user's system. For example, if the end-user display terminal were a small hand-held device then, at present, it would be preferable to do the majority of the image processing at the imaging station. Conversely, if the end-users were a government or scientific organisation then it may be preferable, or necessary, for a larger proportion of the image processing to be done by the user's system.

Following the image processing, if any, performed on the data, the image is displayed. This is done using some digital visual output device, such as a computer monitor, flat screen TV or palmtop display. This process is shown schematically in figure 27.

Now describing the specific configuration of the satellite network having particular regard to how real time global coverage is achieved, reference is made to figures 28 to 31

In the present embodiment, satellites in LEO are provided with the imaging sensors, the sensors being as close as possible to earth to achieve the highest spatial resolution. A LEO-based sensor, however, has a smaller footprint than the same sensor in a higher orbit, so this configuration presents a worse case scenario in establishing the number of satellites required to obtain global coverage of the earth.

Each satellite has optical/IR and active microwave based sensors on board. At present, the maximum spatial resolution of 1 metre for an optical/IR sensor and for microwave sensors is a constraint provided for national security reasons, and not technological reasons. Thus the technology for greater resolution is available for classified purposes, but as yet, has not become available for commercial purposes.

LEOs in the telecommunications and earth imaging industry are usually circular, polar orbits. This orbit ensures that every satellite will pass over an area on the earth at some point in time and have the ability to perform its operational function, with the exception of the far north and south regions. To achieve coverage in these areas, polar elliptical orbits are needed. In the case of circular polar orbits, the satellite is travelling from pole to pole at a constant speed, while the earth is rotating about the polar axis. Figure 28 shows the effect.

Accordingly, the imaging system of the present embodiment comprises a purpose-built LEO imaging satellite constellation travelling in elliptical polar orbits having both microwave and optical sensors.

The satellite network and imaging sensors are configured to cover 95% of the earth's surface. The altitude of the orbit of these satellites is approximately 640 km and the footprint of each satellite's image sensor is circular, as shown in figure 29.

The angle of view from nadir, α in figure 29, is approximately 27° for all sensor types.

The surface area of the whole earth can be calculated as:

$$Area = 4\pi R^2$$

Where the radius of the earth, R, is approximately 6378 km, and so:

$$\text{Surface Area of Earth} = 4\pi(6378)^2$$

$$\approx 5.112 \times 10^8 \text{ km}^2$$

Therefore, the total area to be covered, which is assumed to be 95% of the earth's surface, is:

$$\text{Surface area of earth covered} = 0.95 \times 5.112 \times 10^8$$

$$= 4.856 \times 10^8 \text{ km}^2$$

Now having regard to the coverage of a single sensor, consideration will be made of the sensor parameters and the sensor footprint.

The sensing method adopted by the imaging system of the present embodiment involves having "all-weather" sensors that can move through 360° in azimuth and have a 27° scan angle from nadir. Using this scan angle the sensor can use its 'spot beam' to map out a much larger area. This scan angle is similar to that achieved by the newest of the SPOT imaging satellites, SPOT 5. For simplicity, it is assumed that there is a single type of sensor on the satellite. However, in the present embodiment multiple sensors are used in practice to provide multiple-user access and multi-frequency sensing capabilities. To achieve a 55° (i.e. ±27°) viewing angle, at all azimuths, the sensor needs to be moveable in two planes.

As can be seen from figure 29, the size of the circular footprints is a function of the orbit height of the satellite and the sensor scan angle. To calculate the area of the footprint, consider figure 30.

The area of circular footprint in figure 19 is given by:

$$\textit{Footprint area} = \pi \times (\textit{Footprint Radius})^2$$

$$= \pi \times (\textit{Orbit Height} \times \tan(\alpha))^2$$

$$= \pi \times (640 \times \tan(27°))^2$$

$$= 334073.12 \text{ km}^2$$

It is not possible to provide complete coverage of the earth's surface with circular footprints unless these footprints have a certain degree of overlap. This can be seen in figure 31, which shows the situation for no overlap (figure 31a) and the minimum overlap required for total coverage (figure 31b). As can be seen in figure 31a, with no overlap of the footprints, the sensor beam cannot image some areas.

The effective area covered by a single satellite is the area, which is uniquely (i.e. only) imaged by that satellite. This is given by the square inside the circles in figure 31b.

The area of this square is given by :

$$\textit{Effective Footprint Area} = 2 \times (\textit{Footprint Radius})^2$$

$$= 2 \times (\textit{Orbit Height} \times \tan(\alpha))^2$$

$$= 2 \times (640 \times \tan(27°))^2$$

$$= 212677.58 \text{ km}^2$$

The number of satellites required to image a given proportion of the earth's surface is determined by the size of the area and the coverage of a single satellite. The number is given by:

$$\textit{Number of satellites} = \textit{Area to be covered / Area of Coverage}$$

$$= 4.856 \times 10^8 / 212677.58$$

$$= 2283 \text{ satellites.}$$

Thus, given certain constraints, in the present embodiment a large constellation of around 2000 satellites are needed to cover 95% of the earth's surface. If further overlapping of the footprints is required in order to achieve instantaneous stereo images, this number may need to be increased. Alternatively, the system could either have multiple moveable sensors on the one platform, or a larger scan angle or be in a different orbit. Increasing the scan angle would give a larger effective footprint, as the effective area of coverage. Having a larger effective footprint would reduce the number of satellites required for whole-earth coverage, which is desirable.

It is important to note that the number of satellites required for coverage is primarily related to the effective image footprint of a single satellite. The footprint size is, in turn, critically dependent on the orbit height and sensor scan angle. Thus, the number of satellites required is largely determined by these system parameters and if these are changed then this number may change considerably. Alternatively, the system may configure the satellite constellation to cover a reduced portion of the earth's surface, say North America, which would also reduce the number of satellites required.

The third mode of the invention is substantially similar to the preceding modes. However, as opposed to the previous modes where the image data is obtained directly from satellites traversing the surface of the earth, in the present mode the imaging system that generates the images for display includes a data store means comprising a database within which a virtual model of the earth is generated and stored. This virtual model of the earth is dynamic, being constantly updated by the image data in real time or near real time independently of the user accessing the same, and thus divides the system into two discrete and relatively self-contained subsystems.

The first subsystem involves interaction between the user and the database to access the virtual model of the earth. The second subsystem involves interaction between image gathering satellites, collating and processing of image data obtained thereby, storing this image data in the database to create the virtual model of the earth and constantly updating the virtual model to provide a real time or near real time data model of the earth. This image data on being received on earth is relayed to one or more ground stations, which then transmit the data to the central database from which the data is processed and converted to become or update the virtual model of the earth.

Referring to Figure 32, a block diagram of the imaging system 111 according to the preferred embodiment of the present mode is shown.

The imaging system 111 comprises a plurality of ground stations 300 that receive image data via a satellite receiver (not shown) from the imaging platforms 15 of various satellites 22 constituting the constellar network 21 of satellites. The satellite receiver is in communication with those satellites of the constellar network 21 that are disposed within its sphere of operation.

The ground station 300, as described in the first mode, is in communication with one or more other ground stations that are in turn in communication with different satellites 22 in the constellation within their respective spheres of operation, so that a network of ground stations is provided to receive data from all, or substantially all, of the satellites making up the constellation at any one time.

Each ground station 300 is in turn in communication with an imaging station comprising a central database station 335, where image data gathered by the satellites and relayed by the ground stations 300 is collated and stored, a computer processor 340 where the collated and stored information is retrieved from the central database and is processed to create and update the virtual model of the earth, and an archive database 350 where instances of the dynamically changing virtual model are periodically stored to create a history.

The image data received by each ground station 300 is initially processed before being forwarded to the central database 335. The central database 335 operates to combine the streams of data from the various ground stations 300 so that the data can then be further processed by the computer processor 340 and integrated with previous image data stored in the data store means to create the virtual model 360 of the earth. Images of various regions on the earth's surface 13, and preferably any point on the earth's surface, can be separately accessed on the virtual model of the earth and viewed by users 310 on their PC via a gateway 315 to provide virtual image data of that region or point on the earth in real-time or near real time. Image data constituting the virtual model of the earth is periodically stored in an archive database 350 to obtain a history of the earth model that is separately accessible by a user.

As in the first mode, the imaging system 111 has two levels of encryption for the image data. The first level of encryption applies to information transmitted between satellites 22 of the constellar network 21 and the ground station(s) 300, and the ground station(s) 300 and the central database 335. In the present mode, however, the second level of encryption is applied to image data transmitted between the computer processor 340, the archive database 350 and a user 310. The use of encryption enables the image data to be transmitted over a public network such as the Internet without the data being interpreted by un-authorised users. The two levels of encryption isolate end users 310 from data transmitted by a ground station 300 to the central database 335.

Referring now to Figure 33, a flow chart detailing the method by which the present embodiment of the imaging system operates to generate a virtual model of the earth is shown. The process commences at step 460 where each imaging platform 15 of the constellation of satellites 22 making up the constellar network 21 transmits image data of the earth sensed by the image sensor(s) thereof within the footprint 23 of the imaging platform to one or more ground stations 300 on the earth's surface 13, proximate thereto.

The image data received by a satellite's imaging sensors is compressed prior to transmitting to the ground station(s) proximate thereto. Various means of data compression may be used, however it is preferable that the compression technique be an intra-frame compression technique, such as a technique that transmits the difference between successive image frames.

Once the requested data has been compressed, it is then encrypted before the data is transmitted, to a ground station.

At step 465 the compressed data is received by the ground station and is initially processed by decrypting and expanding it, before transmitting to the central database 335 for combining with other received data at step 470.

The central database 335 receives the decrypted and expanded image data from the various ground stations 300 that are receiving image data from the constellar network 21 of satellites at step 475. The central database 335 integrates and combines the various image data received from the ground stations and transmits it at step 480 as real time or near real time data to the computer processor 340.

The computer processor 340 receives the combined image data from the central database 335 at step 485 and at step 490 converts the data into a virtual model of the earth that is stored in a virtual earth model database.

This conversion is worked between the database store of the central database 335, which provides the real time or near real time update imaging data, and the virtual earth model database of the computer processor 340, which stores all of the previous image data to constitute the latest complete version of the virtual model of the earth before updating with the new image data in relation thereto. Thus, the computer processor 340 is involved with comparing real time or near real time image data received from the central database 335 corresponding to a region of the earth, with the image data stored in the virtual earth model database corresponding to the same region, and applying any changes detected, with the new image data from the central database to update the virtual model of the earth. Thus, the model of the earth is virtual and dynamic with different areas thereof being constantly updated with data received from the central database 335 so that in effect the virtual model is a real time or near real time image of the earth.

In the present mode, the sensor system installed on the imaging platform of some or all of the satellites 22 is substantially the same as that described with respect to the first mode apart from the manner in which it acquires data. Moreover, where in the previous modes the image acquisition operated directly under the control of the user pursuant to the control signals received via the receiver 500 and the processing of the same by the decompression/decryption stage 532, in the preferred embodiment of the present mode, the acquisition of image data by the sensor 500, in the main, operates autonomously in continuously capturing image data, processing and compressing the same, and then transmitting the resultant image data via the transmitter 520 ultimately to a ground station. Thus the control module 535 normally controls the extraction and compression processes performed by the compression module 505 on the data received by the sensor 500 to operate in a continuous acquisition mode and transmit the data ultimately to the proximal ground station thereto.

Referring now to Figure 34, a block diagram showing the structure of a typical ground station 300, and imaging station comprising the central database 335, the computer processor 340, and the archive database 350, as well as the user 310 and gateway 315 according to the embodiment of the present mode is detailed.

The ground station 300 comprises an uplinking section 801 for uplinking satellite control data and a downlinking section 803 for downlinking both image data and control information. The uplinking section 801 receives control data from the computer processor 340 and comprises a data compressor 805 for compressing control data provided thereto from the computer processor 340, an encoder 807 for encoding the compressed data from the data compressor 805 and an uplinking ground station transmitter 809 for transmitting the compressed and decoded control data to a satellite 22. The downlinking section 803 receives encoded and compressed data transmitted by a satellite. The downlinking section 803 comprises a downlinking ground station receiver 811 for receiving decoded and compressed image data and control information from one or more satellites 22, as conveyed thereto from a source imaging platform 15, a decoder 813 for decoding the received image data and control information, and a data de-compressor 815 for decompressing and separating the image data from the control information. The image data and the control information can then be separately transferred, the image data to the central database 335 and the control information to the computer processor 340.

The central database 335 comprises a data processing module 820 for processing decompressed image data transferred thereto from the data decompressor 815 into storable data, and a database store 825 for temporarily storing the processed image data for receipt by the computer processor 340.

The computer processor 340 comprises an image processing module 830, a virtual earth module 835, a request processing module 840, and two control modules for interfacing with the ground station 300, namely a control information processing module 843 and a control signal generating module 847.

The image processing module 830 periodically processes the data stored in the database store 825 to detect the area on the earth's surface that has been transmitted by the satellite and update the image of the virtual model of the earth stored in the virtual earth module 835. The image processing module 830 operates to combine the decompressed image data received from the database store 825 with other image data collected by other satellites that constitutes the virtual model of the earth, continuously, and thus the virtual model of the earth is dynamic and is effectively updated to provide a real-time or near real-time image of the earth.

The request processing module 840 is provided to process requests received from the user 310 via the gateway 315 and a communication network 850 such as the internet. This includes verifying the authenticity of the user and identifying the access level permissions of the user for accessing the virtual model of the earth stored in the virtual earth module 835. The request processing module 840 is also connected to both the control information processing module 843 and the control signal generating module to provide feedback of relevant control information from a satellite 22 to an operator of the satellite, and source control signals to a satellite by the operator. The operator may be either directly connected to the computer processor 340 or indirectly connected via the gateway 315. Thus control information extracted by the data decompressor 815 is transferred to the control information processing module 843 for processing and subsequent supply to the request processing module, and control signals generated by the control signal generating module 847 are transferred to the data compressor 809 for subsequent uplinking to ultimately to the requisite satellite.

The archive database 350 includes an archive database 870 for storing past data images of the virtual world model stored within the virtual earth module 835, and a request processing module 870 for processing received requests via the network 850 that may be sourced by user 310, under the control of the request processing module 840 as necessary.

The gateway 315 includes a user interface 880 for receiving and processing requests from a user 310 and providing responses in response to such requests. A request generating module 885 generates requests from the user 310 for accessing the computer processor 840 and the archive database 350, and the information processing module receives and processes information from the computer processor and archive database to the user. Both the request generating module 885 and the information processing module 890 are directly connected to the network 850 for communicating with the computer processor 340 and archive database 350, as appropriate.

Advantageously, the processing of the data may be performed by high powered personal computers (PCs) and work stations such as those using Microsoft's™ Windows™ operating system or the UNIX™ and LINUX™ operating systems which also work on Sun Microsystems™ workstations.

Referring now to figure 35A, the process by which a user may access the virtual model of the earth, effectively stored in the archive database 350 as updated with data from the central database 335, as a separate sub-system is shown.

The process commences at step 900 where a user 310 sends a request to the gateway 315. The gateway receives the request at 905 and processes the request at step 910. The gateway may incorporate appropriate authentication software to determine whether the user has the requisite permission to access the system, which is determined at step 915. If the user does not have permission, the access is denied as indicated at step 920. On the other hand, if access is allowed then the user may be called upon to particularise their request further, processing of which is undertaken at step 925 and a determination made as to whether this request is viable or not at step 930. For example, the user may request access to a particular region of the world at a particular resolution that may not fall within the permissions allowed to the user, in which case the request is deemed not to be viable and the user is denied access again as represented at step 920. If the request is considered to be viable, the request is then sent to the computer processor 340 as shown at step 935.

As shown at Figure 35B of the drawings, on the computer processor 340 receiving the request, as shown at step 940, the computer processor then processes the request at step 945 and retrieves data from the archive database 350 shown at step 950, satisfying the request of the user. The computer processor 340 then sends this data at step 955 to the gateway where it is received at step 960, whereupon the gateway processes the received data at step 965. The gateway then transmits the data at step 970 to the user who ultimately receives the data at step 975.

An important feature of the present embodiment is that the satellites 22 are controlled to continually acquire images at the highest possible resolution and highest frequency. These images are transferred to the multitude of ground stations 300 and then on to the central database 335 where the image data is subsequently processed by the computer processor 340 and compared with the data stored in the archive database 350 to continuously generate and update a virtual model of the earth.

This model can then be accessed by users 310 through a multitude of gateways 315, which provide different access levels to the virtual model. Moreover, in the present embodiment the model is degraded, for national security reasons, to users having a lower military or security status than other users having a higher status in this regard. Such a degradation system presently exists for US based global position in satellites (GPS) and can be easily adapted for the purposes of implementing the present invention.

To facilitate accommodating these different access levels, the image data is archived within the archive database 350 in a manner so as to provide for different virtual models having different resolutions for prescribed access levels.

Now describing a fourth mode of the invention, reference is made to figures 36, 37A and 37B, as well as to Figures 5A, 5B and 14 of the previous modes.

The fourth mode is substantially similar to the third mode, being directed towards an imaging system essentially comprising the same elements as shown in Figure 32 of the drawings, namely a large constellation of satellites 22 that can image all, or some portion, of the earth's surface 13 continuously and transfer this information via ground stations 300 to a central database station 335 for processing by a computer processor 340 and updating an archive database 350, which is accessible by an end-user 310 via a gateway 315 with minimal delay.

However, as opposed to the imaging platforms operating to acquire images at a predetermined resolution and rate of capture continuously without user interaction and relying upon the computer processor for prescribed degradation of the result in data images to match user access permissions, the fourth mode provides for user interaction with the acquisition of images by the imaging platforms to alter the resolution and image capture rate on the platform itself.

The real time imaging system of the preferred embodiment of the fourth mode in terms of general structure is substantially the same as that of the third embodiment. Accordingly, the block diagrams of the imaging system shown in Figures 32, 5A, 5B (from the first embodiment) and 34 of the drawings are equally applicable to the present embodiment.

With respect to Figures 5A and 5B, the operation of the compression and control system provided on the imaging platforms in the present embodiment, is the same as for the third mode, except that the receiver 525 and the decompression/decryption stage 532 are used to provide for user interaction with the imaging platform to change it from operation in a continuous acquisition mode to a remote control mode, similar to the first mode. Moreover, in the remote control mode, the control module 535 receives expanded data from the decoder and expander module. The control module 535 operates to compare data received from the sensor 500 uplinked with reference data received from the decoder and expander module 530. This comparison enables the control module 535 to determine which portion of the data fed to the data store 510 from the sensor 500 corresponds with data received from the decoder and expander module 530.

Having determined which portion of the data received by the sensor 500 is required for transmission to a ground station, the control module 535 controls the extraction and compression processes performed by the compression module 505 on the data received by the sensor 500 in accordance with the control signals received by the receiver 525.

The imaging station as shown in Figure 34 of the drawings also operates differently from the imaging station described in relation to the third embodiment in order to provide for changing the imaging platform from operating in the continuous acquisition mode to operating in the remote control mode. In this arrangement, a user 310 having the requisite permission for accessing the system so as to effect control of the constellar network of satellites remotely in order to obtain, for example, a better spatial resolution of the image data in respect of a prescribed region of the earth and/or a better temporal resolution of the prescribed region, issues a request via the gateway 315 to the computer processor 340. On the request processing module 840 determining the viability of the request, the control signal generating module 847 is invoked to generate the requisite request, which is then transferred to the uplinking station 801 of the ground station 300 for uplinking to the appropriate satellites 22 and imaging platforms 15 thereof to effect the request.

In this manner, a user having the requisite permission for accessing the imaging system at this level of operation can control the imaging platform 15 to provide higher spatial resolution, for example less than 1 metre, combined with higher temporal resolution, for example greater than 25 ‘images’ per second, to allow for higher order viewing of a prescribed region of the earth and indeed allow for the generation of a ‘movie quality’ video of activities occurring in real time or near real time of a prescribed region of the earth imaged by one or more imaging platforms, for any particular purpose.

In order to achieve this, the imaging system needs to provide for very fast transfer and processing in order to achieve real time or near real time creation and updating of the virtual model of the earth, which increases the overhead processing time of the system from its normal operating requirement and so may be delivered to those users prepared to pay a premium for the facility, or for users having a privileged level of security.

A top-level schematic of the imaging process in the remote control mode is shown in Figure 36. The process commences with the user 310 requesting an image at step 1000. This request is then processed by the request processing module 840 to determine how the request is to be implemented at step 1010, and then the information is uplinked to the appropriate imaging satellites 22 by the uplinking section 801 at step 1020. The satellite’s image platform 15 acquires the requested image at step 1030, which is then downlinked to ground at step 1040 and processed at the imaging station at step 1050. Lastly, the image is transferred to and displayed on a visual output device for the user 310.

Now describing the method of operation in more detail, as shown in Figure 37A of the drawings, the user 310 sends a request for a more detailed view of a prescribed region of the earth to the gateway 315 at step 1101. The gateway 315 receives the request at step 1103 and processes the request at step 1105 to determine whether the request is allowable as shown at step 1111.

As indicated in the preceding embodiment, this processing is associated with determining the permission level of the user and whether they are entitled to more detailed access of the virtual model of the earth as stipulated by the service provider of the imaging system.

If the request is not allowable, the user is denied access at step 1109. However, if the request is allowable, the gateway processes the request further at step 1113 to determine whether the request is viable at step 1115. The viability of the request is concerned with ascertaining whether the level of detail requested is possible at that time and can be scheduled or whether the system is unavailable for that task. If the request is not considered to be viable, the user is denied access again at step 1109, but if the request is viable, the request is then sent to the computer processor 340 by the gateway 315 at step 1117.

As shown at Figure 37B, on the computer processor 340 receiving the request at step 1119 the computer processor proceeds with processing the request at step 1121 and sending the request to the ground station via the request generating module 847 at step 1123. On the ground station 300 receiving the request at step 1125 the uplinking section 801 of the ground station sends the request to the imaging satellites 22 at step 1127.

On the satellite including the particular imaging platform that is determined to obtain the more detailed image of the prescribed area of the earth receiving the request at step 1129, the imaging platform 15 thereof processes the request at step 1131.

As shown in Figure 37C the imaging platform deals with single requests or multiple requests by determining whether the transmission of the request or requests is at an end point at step 1133, after the ground station sends the request at step 1127 and the satellite receives and processes the request at step 1129. If the request is the final request, then the control system of the platform completes the downlinking of image data at step 1135 pursuant to the request, and returns the imaging platform to the continuous acquisition mode at the prescribed resolution. On the other hand, if a further request is scheduled to be processed, the satellite proceeds with processing the next request at step 1137, controlling the resolution of the sensor appropriately and sending the acquired image data at step 1139 back to the ground station 300. The imaging platform then considers whether the transmission is at and end point yet, and if so, completes the data transfer at step 1135.

As shown in Figure 37D of the drawings, after the ground station 300 receives downlinked image data at 1141, it proceeds with sending this data at step 1143 to the central database 335, where it is stored and accessed by the computer processor at step 1145. The computer processor 340 then sends the data via the request processing module 840 and the network 850 to the gateway 315 at step 1147. The gateway 315 on receiving the enhanced image data at step 1149, then processes the data at step 1151 and transmits the data at step 1153 to the user 310 who ultimately receives the same at step 1155.

It should be appreciated that an advantage of combining the image data into the virtual model of the earth is that it decreases the need for the acquired images to be archived. Instead, the "virtual world imaging" file can be saved on a regular basis and act as a revision for comparison in the future for a variety of purposes.

Another advantage of the system is that no complex components are designed into the satellites. The satellites represent a standard unit that can be periodically replaced when needed.

Another advantage of the present invention is that the images can be acquired in such a way that a video feed into the virtual world model can be achieved providing a real time 3D model of the world.

A further advantage is that favourable resolution/signal-to-noise ratio trade offs can be made through signal averaging.

It should be appreciated that the scope of the present invention is not limited to the scope of the particular embodiments described herein. As is evident from the description there are different combinations of features and variations that can be provided and would be apparent to a skilled person in the field of the invention, which whilst not being one of the specific embodiments, nonetheless fall within the scope and spirit of the invention.

The Claims Defining the Invention are as Follows

1. An imaging system for providing image information of a desired portion of the earth's surface to a user of the system in real or near real time comprising:-

(a) a large number of imaging platforms in non-geostationary earth orbits,

(i) each platform having one or more imaging sensors; and

(ii) the platforms being arranged in a constellar network so that the footprint coverage of the imaging sensors of each platform is adjacently and overlappingly disposed with respect to the footprints of each adjacent platform thereto, so that the footprints contiguously and concurrently cover a substantial part of the earth's surface continuously and dynamically; and

(a) communication means for conveying information between a user requesting an image of the desired portion of the earth covered by the footprints and the network of platforms providing same.

2. An imaging system as claimed in claim 1, wherein the platforms form a constellation of satellites.

3. An imaging system as claimed in claim 1, wherein said sensors for collecting said image data are located by aircraft such as high altitude balloons or unmanned remote controlled aircraft above the earth, or on any celestial bodies that provide line of sight viewing of the earth.

4. An imaging system as claimed in claim 2, wherein said aircraft are arranged or said celestial bodies are disposed so as to form said constellation.

5. An imaging system as claimed in any one of the preceding claims, wherein any portion of the earth's surface within the footprint coverage being capable of being imaged any time with a spatial resolution of approximately 1 metre or

less and a temporal resolution of approximately 25 images per second or more.

6. An imaging system as claimed in any one of the preceding claims, wherein said communication means comprises high bandwidth links such as optical with suitable encryption and compression.

7. An imaging system as claimed in any one of the preceding claims, wherein said communication means includes:

   (i) request delivery means to deliver a processed request for an image from the user to the platform(s) required to generate the image requested; and

   (ii) image delivery means to deliver the image generated by the platform(s) to the user.

8. An imaging system as claimed in claim 7, including an image request processing station comprising:

   (a) an image requesting server to receive compiled requested information from the user;

   (b) data processing means to generate processed image request data including:

      (i) location processing means for determining the location and size of the portion to be viewed and the time duration of the imaging;

      (ii) permission processing means to determine user access;

      (iii) resource allocation means to determine requisite resources such as platforms and sensors to provide the image;

      (iv) scheduling means to schedule the use of the resources amongst competing requests; and

(v) request data transport means to transport processed image request data via the request delivery means.

9. An imaging system as claimed in claim 7 or 8, including image data acquisition and processing means disposed on each platform including:

(a) data receiving means for receiving the processed request data;

(b) data processing means to process the received processed request data and to control the imaging sensors in accordance therewith;

(c) a data storage area to store data output from the imaging sensors;

(d) control and processing means to process the stored data to generate processed image data ready for transport; and

(e) image data transport means to transport processed image data via said image delivery means.

10. An imaging system as claimed in any one of claims 7 to 9, including an image receipt processing station for processing received processed image data including:

(a) receiving means to receive and initially process the transported image data for decompression, decryption and the like;

(b) pre-processing means to calibrate, enhance and classify the initially processed image data if necessary;

(c) extracting means to extract the portion of the image originally selected by the user;

(d) transport processing means to process the extracted image data ready for delivery to the user; and

(e) transmission means to transmit the processed extracted image data to the user.

11. An imaging system as claimed in claim 10, wherein said image receipt processing station includes combining means to combine the initially processed image data with other image data, possibly collected by other satellites, so as to produce a real-time or near real-time combined image of the selected area.

12. An imaging system as claimed in any one of claims 7 to 11, including an earth imaging application means comprising:-

(a) a user request interface that is real-time interactive having:

(i) selection means to select a portion of the earth that is desired to be imaged by the user;

(ii) zooming means to fine tune the selection of the portion;

(iii) resolution means to select the desired resolution of the image;

(iv) frequency sampling means to select the desired sampling frequency of the image; and

(v) view formatting means to select the dimension in which the image is viewed and video or static views;

(b) compilation means for compiling requested information;

(c) transmission means to transmit requested information to the image requesting server; and

(d) a user image display interface integrated with the user request interface to display the requested image in real time or near real time, including:

(i) image processing means to process the received extracted image data from the image processing station for display; and

(ii) display means for displaying the processed image data to the user.

13. An imaging system as claimed in claim 11, or claim 12 as dependent on claim 11, wherein said image data comprises three-dimensional data of the earth's surface whereby the combined image is a three dimensional image.

14. An imaging system as claimed in claim 11 or any one of claims 12 or 13 as dependent on claim 11, wherein said image data comprises two-dimensional data of the earth's surface whereby the combined image is a three dimensional or stereoscopic image.

15. An imaging system as claimed in any one of the preceding claims, wherein more than one sensor is provided on each platform to collect optical data.

16. An imaging system as claimed in any one of the preceding claims, wherein one or more sensors are provided on each platform to detect and collect image data on a number of frequencies beyond optical frequencies such as micro-wave, infra-red, ultra-violet or gamma radiation frequencies.

17. An imaging system as claimed in any one of the preceding claims, wherein said platforms are adapted so that image data of at least one area of the earth's surface is collected by at least two sensors at any one point in time whereby said platforms collect said three dimensional data.

18. An imaging system as claimed in any one of claims 1 to 16, wherein said three dimensional data of an area is collected by a single sensor from two different points of an orbit of a platform containing said sensor.

19. An imaging system as claimed in any one of the preceding claims, wherein said sensor collects said data sets at a rate of 25 data sets per second or higher as the platform traverses its orbit path.

20. An imaging system as claimed in any one of the preceding claims as dependent on claim 11, wherein said platforms are further adapted to communicate with each other so that said image data of an area collected by at least two sensors is filtered by said platforms so that said combining means receives a selected set of image data of said area.

21. An imaging system as claimed in any one of claims 1 to 7, 9, 11, or 13 to 20, including:

(a) data store means to continuously store and integrate image data from said image sensors to form a virtual model of the earth, said data being accessible for viewing desired portions of said virtual model;

(b) first communication means to deliver said image data continuously from said platforms to said data store means for storage and integration thereby; and

(c) second communication means for conveying information between a user requesting an image of the desired portion of said virtual model and the data store on demand.

22. An imaging system as claimed in claim 21, wherein the first communication means includes a plurality of ground stations that receive the image information from the platforms and transfer the information to the data store means, and the data store means includes a central database for integrating and storing image data received from each of the ground stations.

23. An imaging system as claimed in claim 22, wherein the central database is updated periodically from the ground station.

24. An imaging system as claimed in claim 22 or 23, wherein a computer system accesses the central database and processes the images to create a virtual model of the earth.

25. An imaging system as claimed in claim 24, wherein the virtual model is capable of being viewed in 2D and 3D.

26. An imaging system as claimed in claim 24 or 25, wherein the virtual model of the earth is connected to a variety of gateways such that users may access the virtual model.

27. An imaging system as claimed in any one of claims 24 to 26, wherein the virtual model is capable of being degraded to provide a lower resolution image.

28. An imaging system as claimed in claim 27, wherein the level of access depends upon the privilege rating of the user, certain users with high privilege ratings having access to the highest resolution images, while the lower resolution images are made available to users with lower privilege ratings.

29. An imaging system as claimed in claim 27 or 28, wherein the communication means is adapted to inform the relevant platforms to transfer images of a higher order to the ground station and thus to the computer processor if a higher resolution or higher refresh rate is required by a user or plurality of users.

30. An imaging system as claimed in any one of claims 24 to 29, wherein the virtual world model is periodically archived.

31. An imaging system as claimed in any one of claims 24 to 30, including a computer processor comprising various means to interact with the central database, means to interact with the user gateways and means to create a real time virtual model of the earth.

32. An imaging system as claimed in claim 30 as dependent on claim 26, wherein the gateway comprises various means to interact with the user and the central computer to process user requests and provide the user with various image data output from the computer processor.

33. An imaging system as claimed in claim 32, wherein the gateway interacts with the computer processor through networking means.

34. An imaging system as claimed in claim 33, wherein the gateway uses the Internet to interact with the computer processor.

35. An imaging system as claimed in any one of the preceding claims, wherein images are acquired via the platforms on a continual basis over an area or footprint defined by the imaging hardware.

36. An imaging system as claimed in any one of claims 24 to 34, wherein the virtual model is updated according to user requirements through communication means with the platforms.

37. An imaging system as claimed in any one of the preceding claims, wherein at least one platform operates within the Lagrange points within the solar system.

38. An imaging system as claimed in claim 37, wherein the Lagrange points are the earth-moon Lagrange points.

39. An imaging system as claimed in claim 38, wherein the earth-moon Lagrange points are the stable Lagrange points known as L4 and L5.

40. An imaging system as claimed in any one of the preceding claims, including communication platforms for transferring data from said imaging platforms to the earth to focus the imaging platforms capabilities towards increasing the effectiveness and efficiency of the system and rely upon the communication platforms for effecting high level communications with the earth.

41. An imaging system as claimed in claim 40, wherein said communication platforms operate in a higher orbit to cover a number of imaging platforms and ground stations.

42. An imaging system comprising a large constellation of platforms collectively having a first set of passive electromagnetic radiation sensors and a second set of active electromagnetic radiation sensors, each sensor being adapted to collect data from the earth's surface; identification means for identifying an area on the earth's surface from where data has been collected by said passive sensor; comparison means for comparing said identified area with a target area; whereby in response to a positive result of said comparison, said active sensor is adapted to collect data from said identified area.

43. An imaging system as claimed in claim 42, further comprising a set of images of the earth's surface; said comparison means adapted to compare said data collected by said passive sensor with said set of images.

44. An imaging system as claimed in claim 42 or 43, wherein said second set of active sensors are wide range sensors.

45. An imaging system as claimed in any one of claims 42 to 44, wherein said sets of active sensors and passive sensors are adapted to receive electromagnetic radiation from a spread of frequencies, such as optical, infra-red, ultra-violet and microwave frequencies; and said set of image data being derived from said spread of frequencies.

46. A system for collecting data related to the earth; said system comprising a constellation of platforms some or all of which contain a set of sensors for detecting electromagnetic radiation emitted from the earth's surface; processing means for receiving at least two sets of data; each said set of data being received from a separate one of said platforms; and said processing means combining said at least two sets of data to generate a representation of the earth.

47. A system as claimed in claim 46, wherein said sensors operate to detect a pre-determined set of electro-magnetic radiation frequencies including optical, infra-red, ultra-violet and microwave frequencies whereby said representation is generated, at least in part, from data collected from electromagnetic frequencies outside the optical range of frequencies.

48. A system as claimed in claim 46 or 47, wherein said representation comprises a graphical or visual representation of said data.

49. An imaging system for generating graphical representations of the earth comprising input means for receiving input data from a large constellation of platforms orbiting the earth; processing means for processing said data to generate a set of image data of the earth; and imaging means for generating graphical representations of the earth from said set of image data.

50. An imaging system as claimed in claim 49, wherein the platforms are satellites.

51. An imaging system as claimed in claim 50, wherein said input data comprises communications signals received by a constellation of communications satellites; and said processing means is adapted to process said communications signal to identify sets of image data of the earth.

52. An imaging system as claimed in claim 51, wherein said constellation of communications satellites have a non-stationary orbit and collectively receive communication signals on a continuous basis from a predetermined area of the earth's surface, whereby said processing means updates said set of image data on a real or near real time basis.

53. An imaging system as claimed in any one of claims 46 to 52, wherein said set of image data comprises data in three dimensions.

54. An imaging system as claimed in any one of claims 46 to 53, wherein said imaging means access said data in three dimensions whereby said graphical representations are three-dimensional representations.

55. An imaging system as claimed in any one of claims 46 to 54, wherein alternatively or additionally to obtaining data signals from satellites, said data signals are obtained from telecommunications receivers located in high altitude balloons, aircraft, including high altitude unmanned reconnaissance/communications aircraft.

56. An imaging system as claimed in any one of claims 46 to 55, wherein said set of image data comprises a virtual model of the earth.

57. A method for providing image information of a desired portion of the earth's surface to a user in substantially real time comprising:-

(a) imaging the earth from a plurality of platforms located above the earth's surface;

(b) arranging the platforms in a constellar network with the footprint coverage of the imaging that can be achieved from each platform adjacently and overlappingly disposed with respect to the footprint coverage of the imaging from each adjacent platform thereto so that the footprints contiguously and concurrently cover a substantial part of the earth's surface continuously and dynamically; and

(c) conveying imaging information to a user requesting an image of the desired portion of the earth covered by the footprints and the network of platforms providing the imaging.

58. A method as claimed in claim 57, including spatially resolving the imaging of any portion of the earth's surface within the footprint coverage at any time to approximately 1 metre or less and temporally resolving the imaging to approximately 25 images per second or more.

59. A method as claimed in claim 57 or 58, wherein the conveying includes:

(i) delivering a request for an image from the user to the platform(s) required to perform the imaging to generate the image requested; and

(ii) delivering the image generated by the platform(s) to the user.

60. A method as claimed in claim 57 or 58, including:

(a) conveying information from the network of platforms providing the imaging to a central data store;

(b) processing and integrating said information with previous data gathered to provide a virtual model of the earth; and

(c) making image data in respect of said virtual model accessible to various users via a gateway.

61. An imaging system for providing image information of a desired portion of the earth's surface to a user of the system substantially as herein described in any one of the modes, with reference to the accompanying drawings as appropriate.

62. A method for providing image information of a desired portion of the earth's surface to a user substantially as herein described in any one of the modes with reference to the accompanying drawings as appropriate.

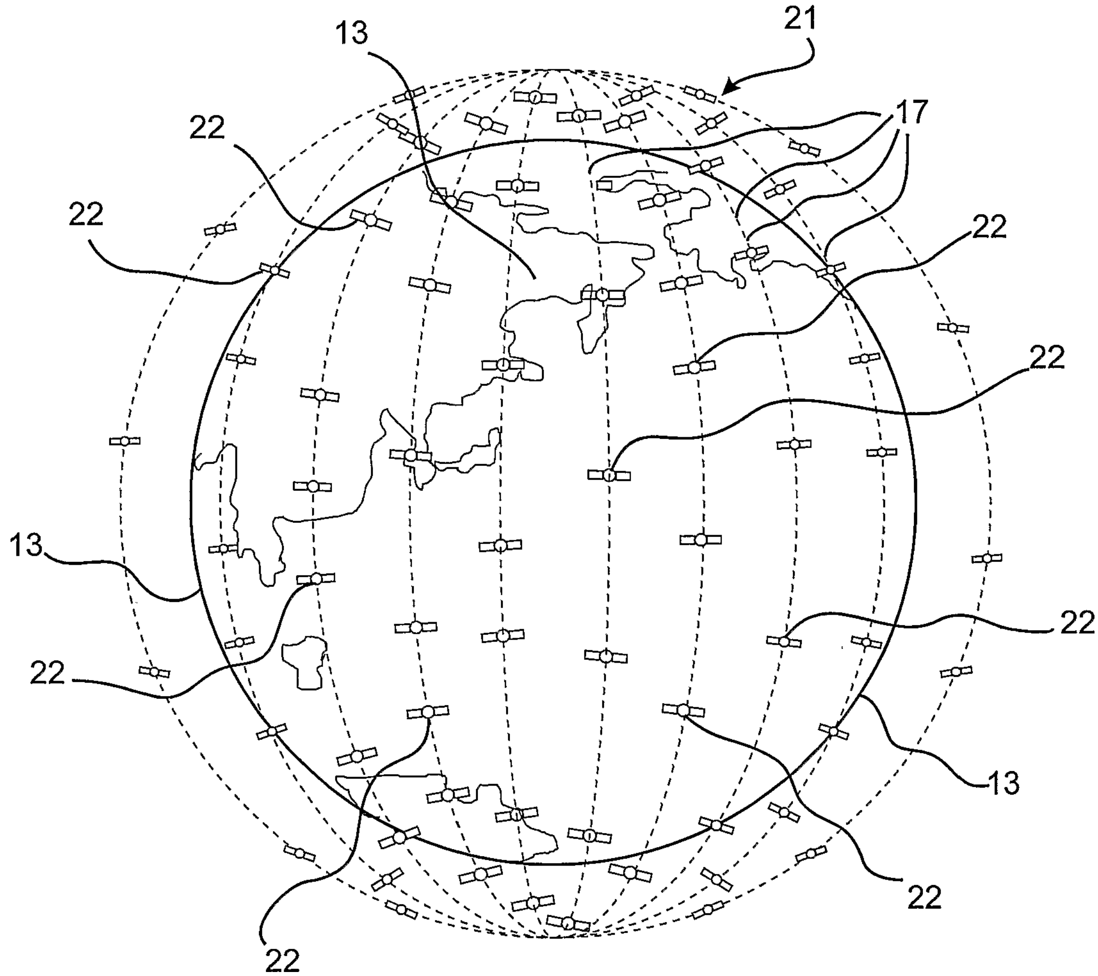


Fig.1

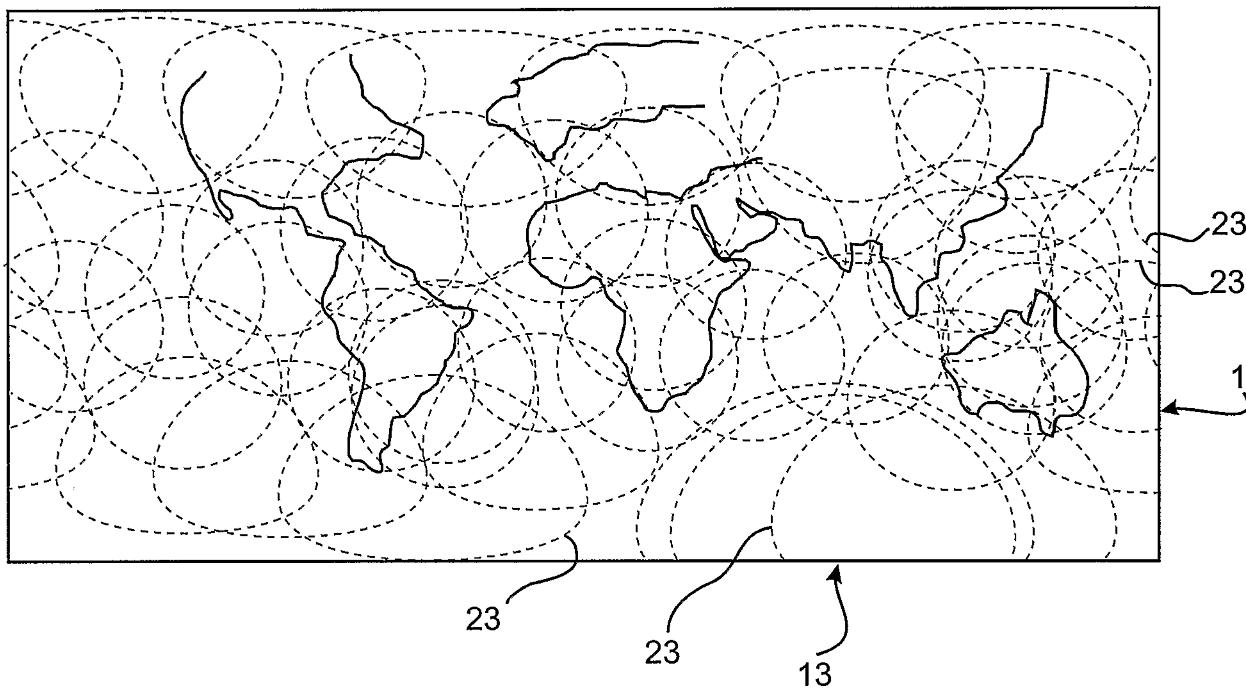


Fig 2

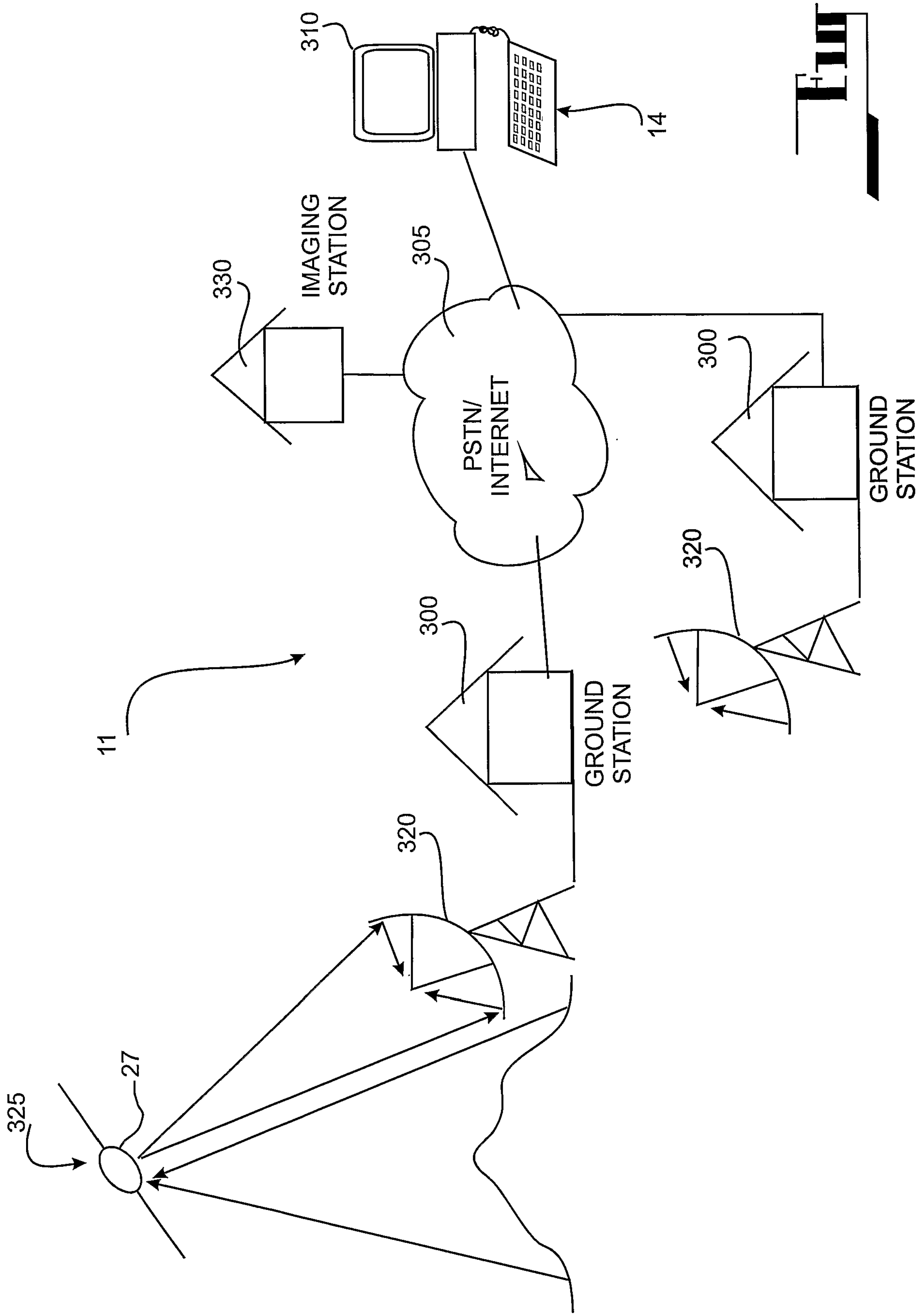

310
14
IMAGING STATION
330
305
PSTN/ INTERNET
300
GROUND STATION
320
300
GROUND STATION
320
11
325
27

Fig. 3.

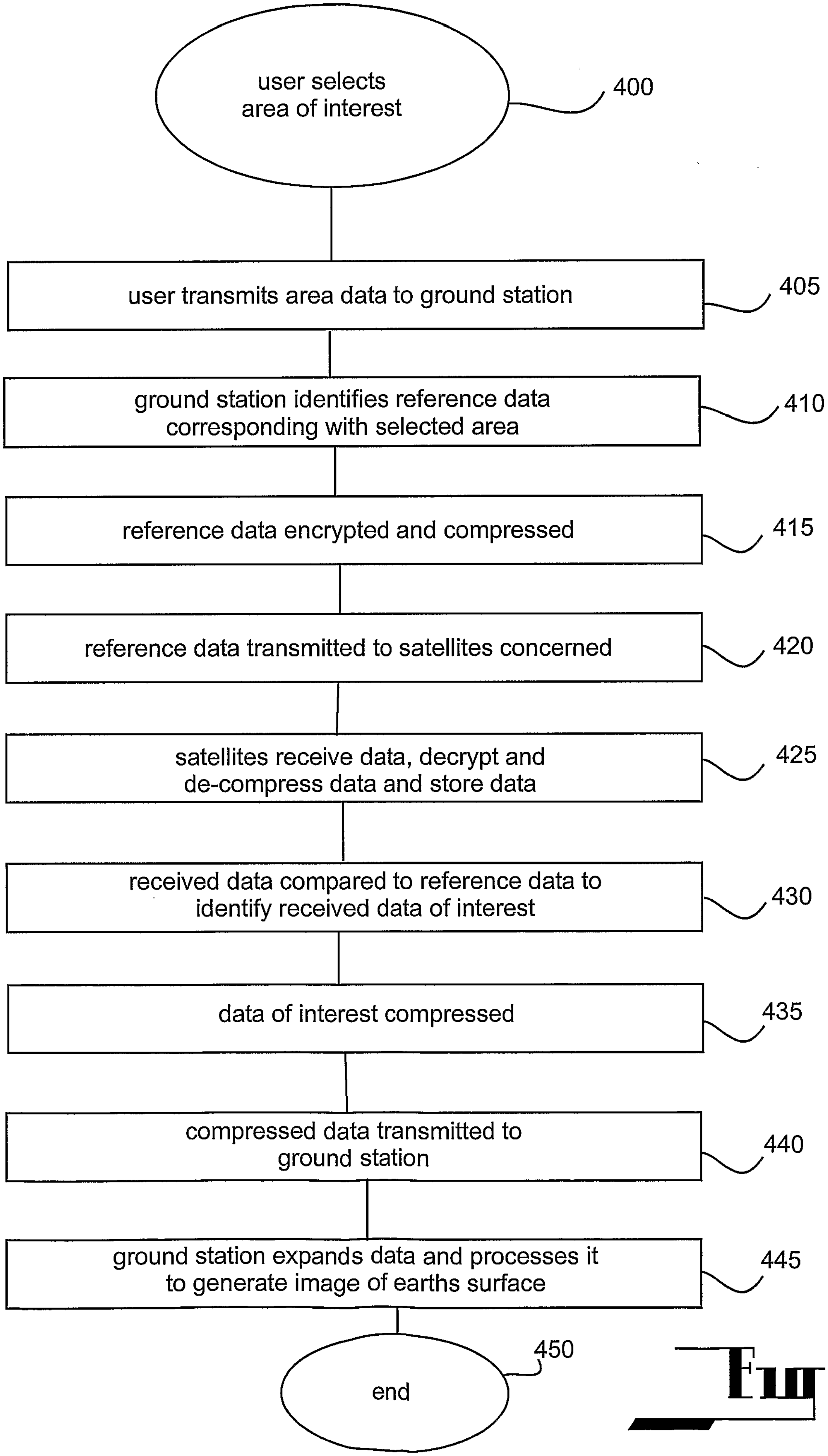

user selects area of interest
400
user transmits area data to ground station
405
ground station identifies reference data corresponding with selected area
410
reference data encrypted and compressed
415
reference data transmitted to satellites concerned
420
satellites receive data, decrypt and de-compress data and store data
425
received data compared to reference data to identify received data of interest
430
data of interest compressed
435
compressed data transmitted to ground station
440
ground station expands data and processes it to generate image of earths surface
445
end
450

Fig. 4

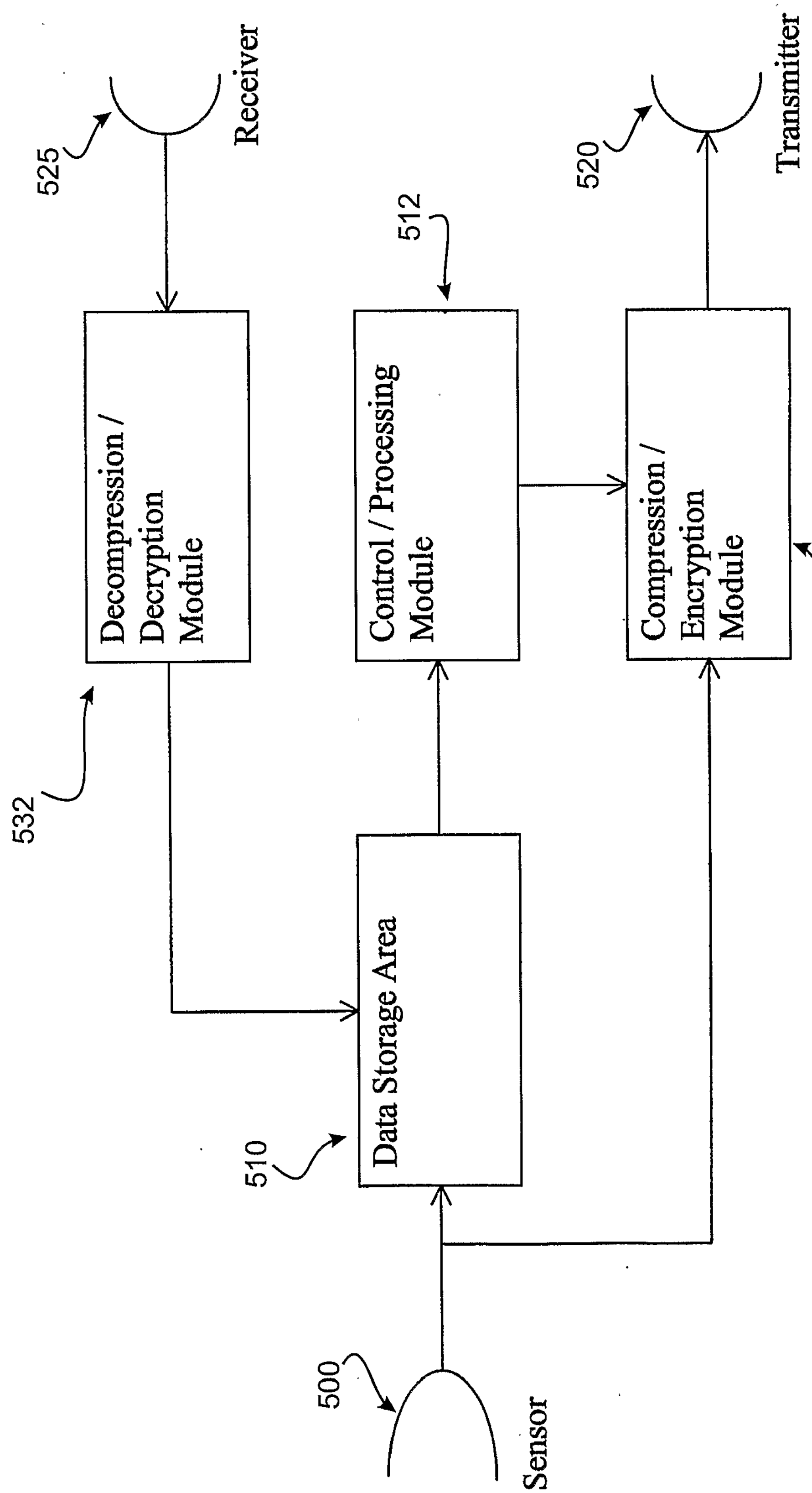

Receiver
525
Transmitter
520
512
Decompression /
Decryption
Module
Control / Processing
Module
Compression /
Encryption
Module
507
532
Data Storage Area
510
500
Sensor

Fig. 5a

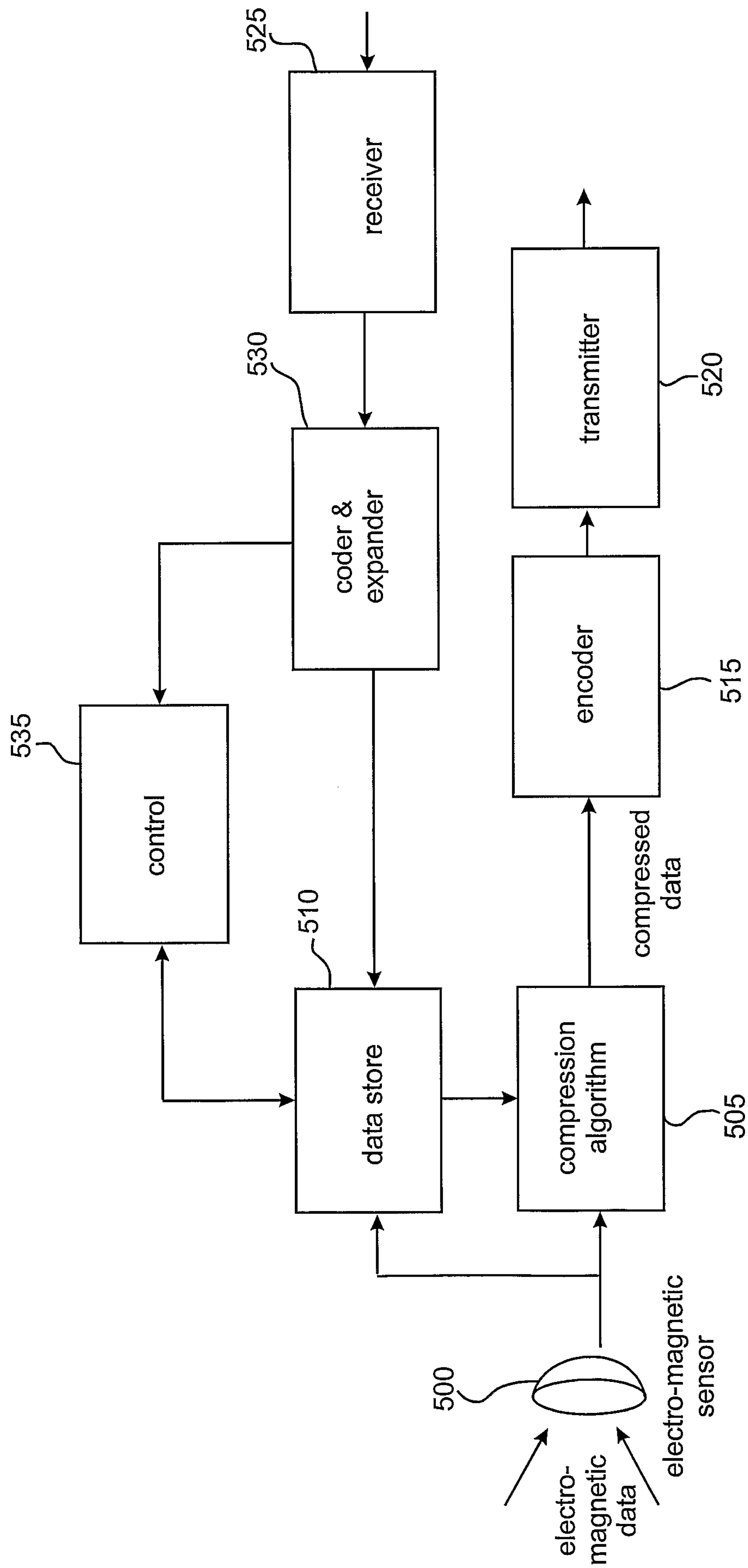

525
receiver
530
coder & expander
535
control
510
data store
505
compression algorithm
compressed data
515
encoder
520
transmitter
500
electro-magnetic sensor
electro-magnetic data

Fig. 5b

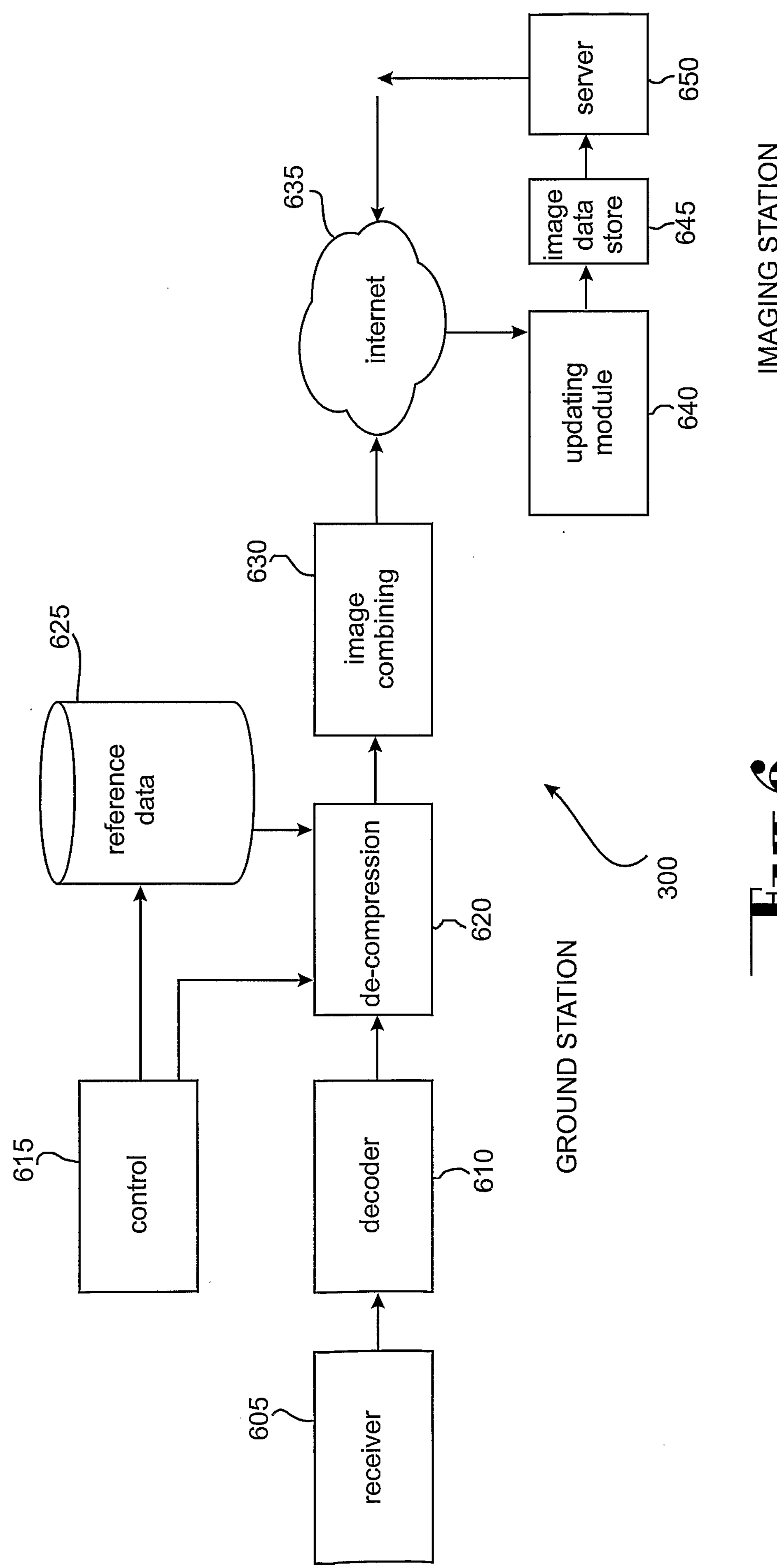

receiver
605
decoder
610
control
615
de-compression
620
reference data
625
image combining
630
internet
635
updating module
640
image data store
645
server
650
GROUND STATION
IMAGING STATION
300

Fig 6a

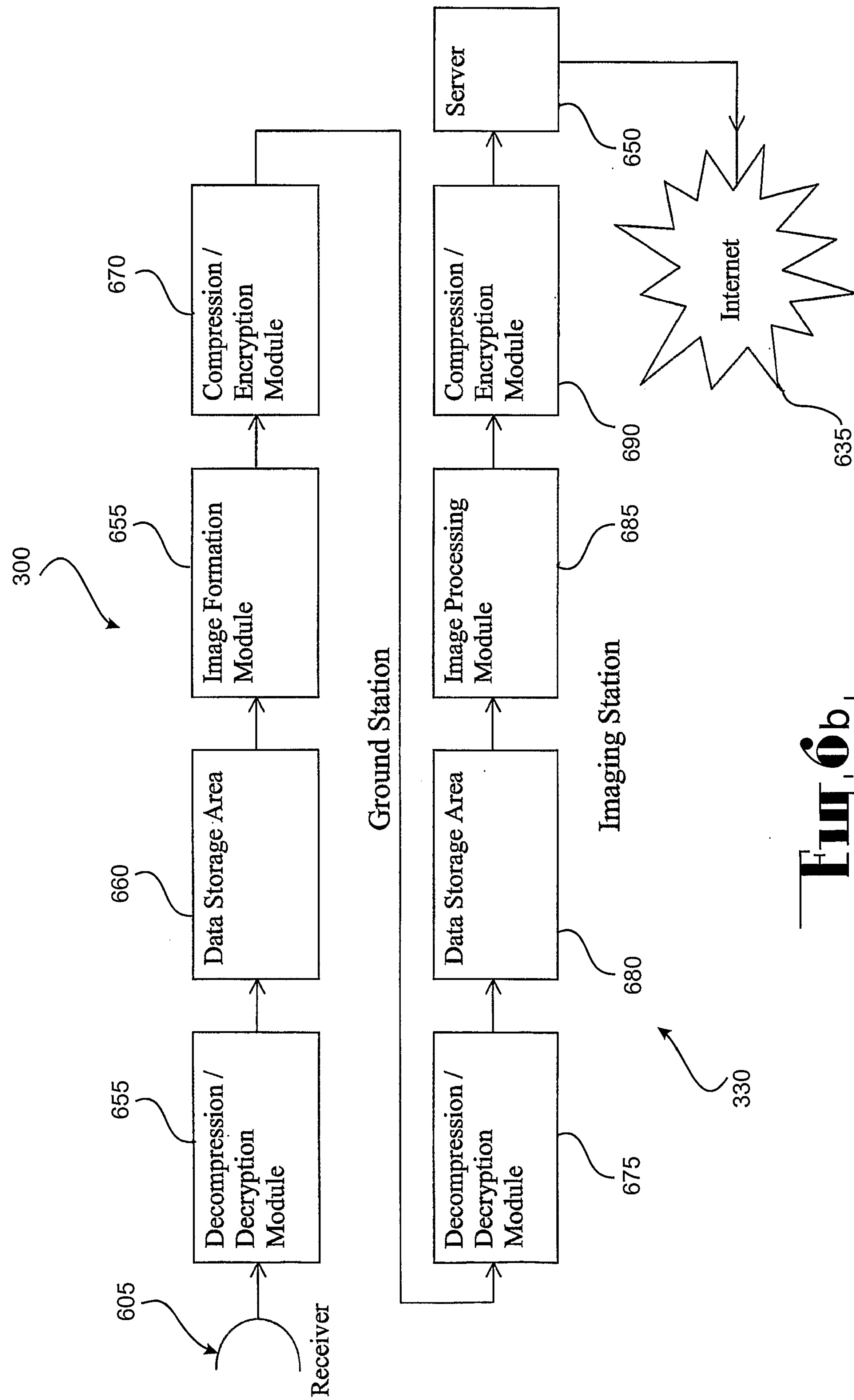

300
Receiver
605
Decompression / Decryption Module
655
Data Storage Area
660
Image Formation Module
655
Compression / Encryption Module
670
Ground Station
Decompression / Decryption Module
675
Data Storage Area
680
Image Processing Module
685
Compression / Encryption Module
690
Server
650
Internet
635
Imaging Station
330

Fig. 6b

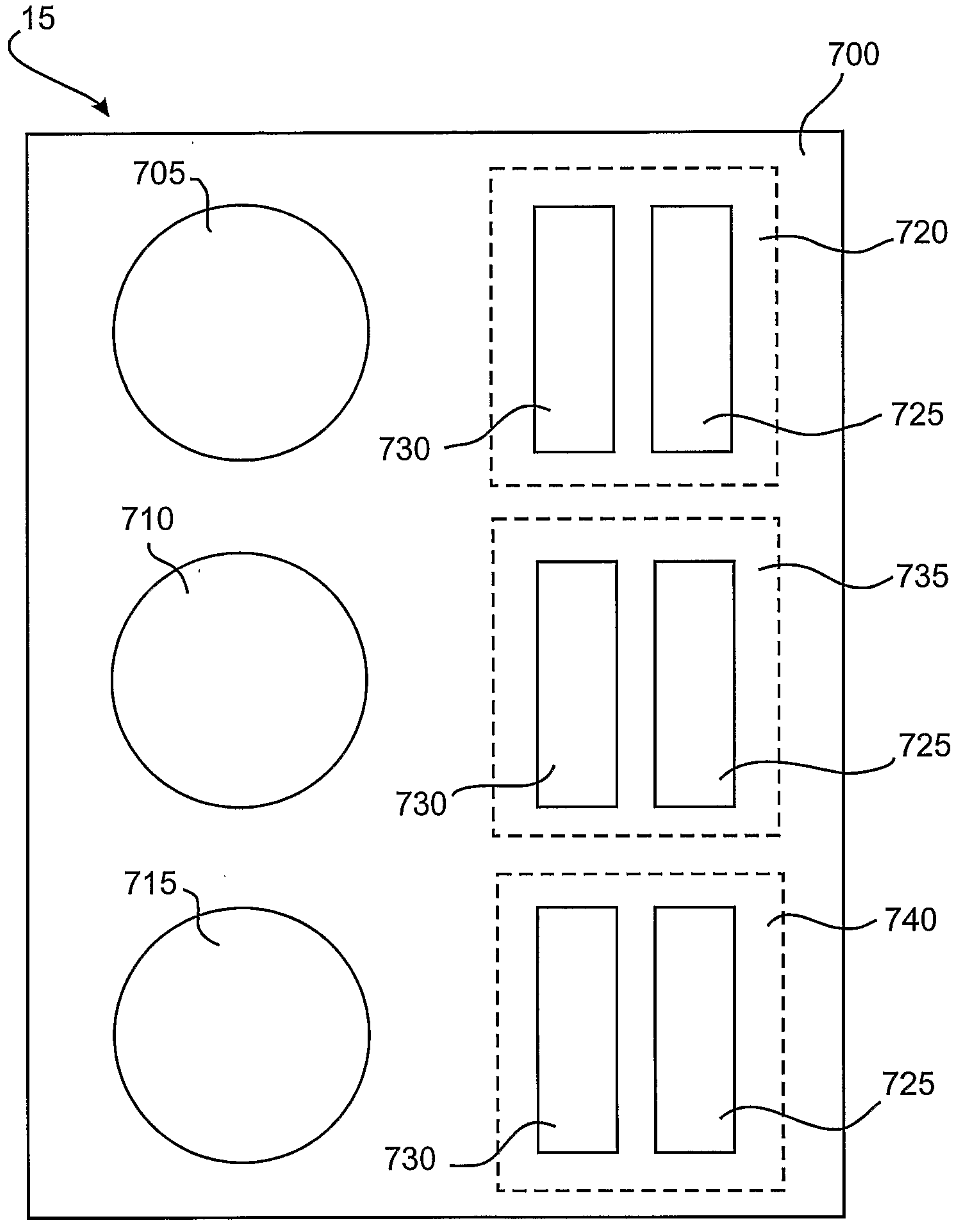
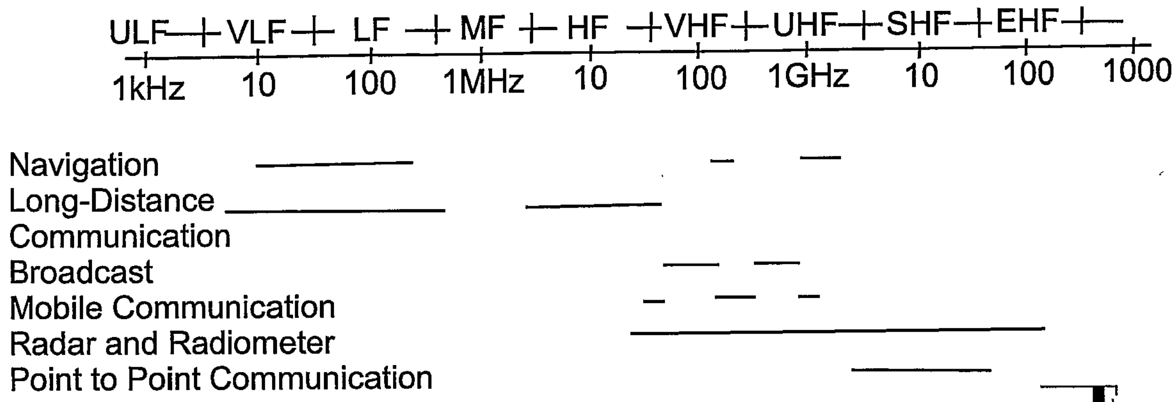
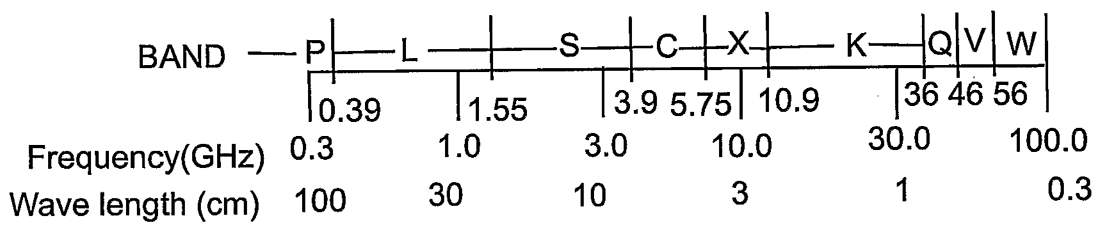


Fig 7



(a) The Radio Spectrum

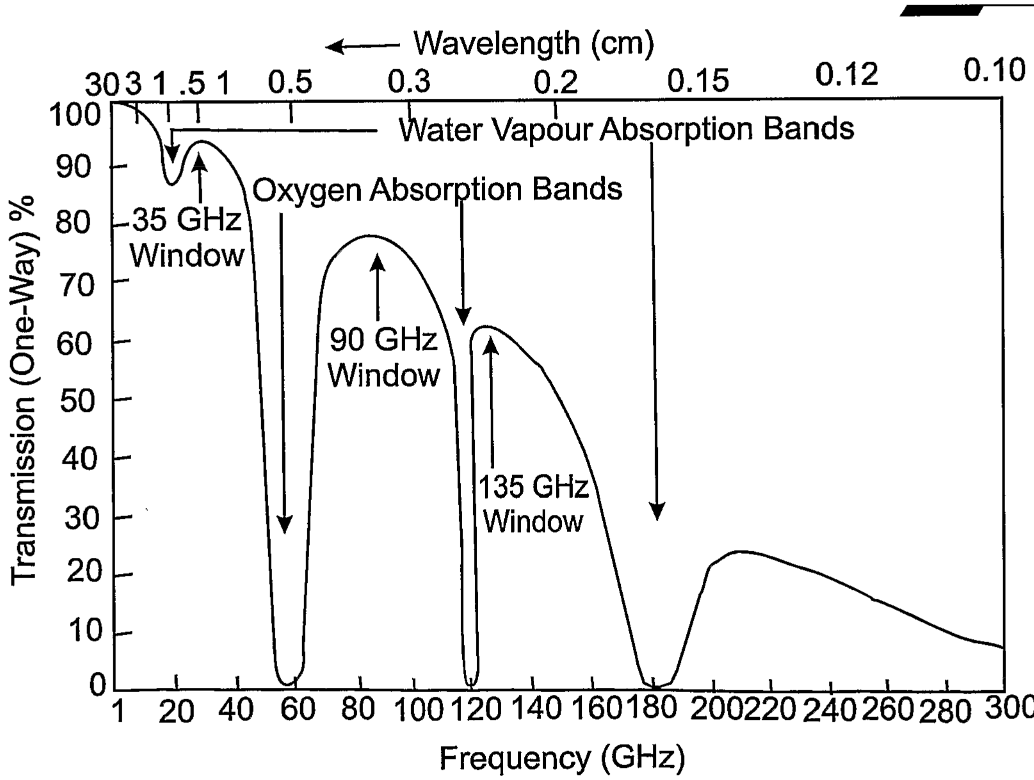
Fig. 8a



(L) The Microwave Spectrum

(a) Band designation of the radio spectrum and (b) letter designation of th microwave portion.

Fig. 8b



Percentage transmission through the earths atmosphere, along the vertical direction, under clear sky conditions.

Fig. 9

Passive Sensor Frequency Allocations (Ghz)

0.404-0.406a	10.60-10.68p	36-37p	150-151p
1.370-1.400s	10.68-10.70a	50.2-50.4p	164-168a
1.400-1.427a	15.20-15.35s	51.4-54.25a	174.5-176.5p
1.6605-1.6684p	15.35-15.40a	54.25-58.2	182-185a
2.640-2.600s	18.6-18.8s	58.2-59.0a	200-202p
2.690-2.700a	21.2-21.4p	64-65a	217-231a
4.2-4.4s	22.21-22.5s	86-92a	235-238p
4.80-4.99s	23.6-24.0a	100-102p	250-252a
6.425-7.250s	31.3-31.5a	105-116a	
10.6-10.68p	31.5-31.8p	116-126p	

a Protected for radio astronomy -no transmitters allowed
p Shared. Primary use is for services having transmitters
s Shared. Secondary use is for services having transmitters

Fig.10.

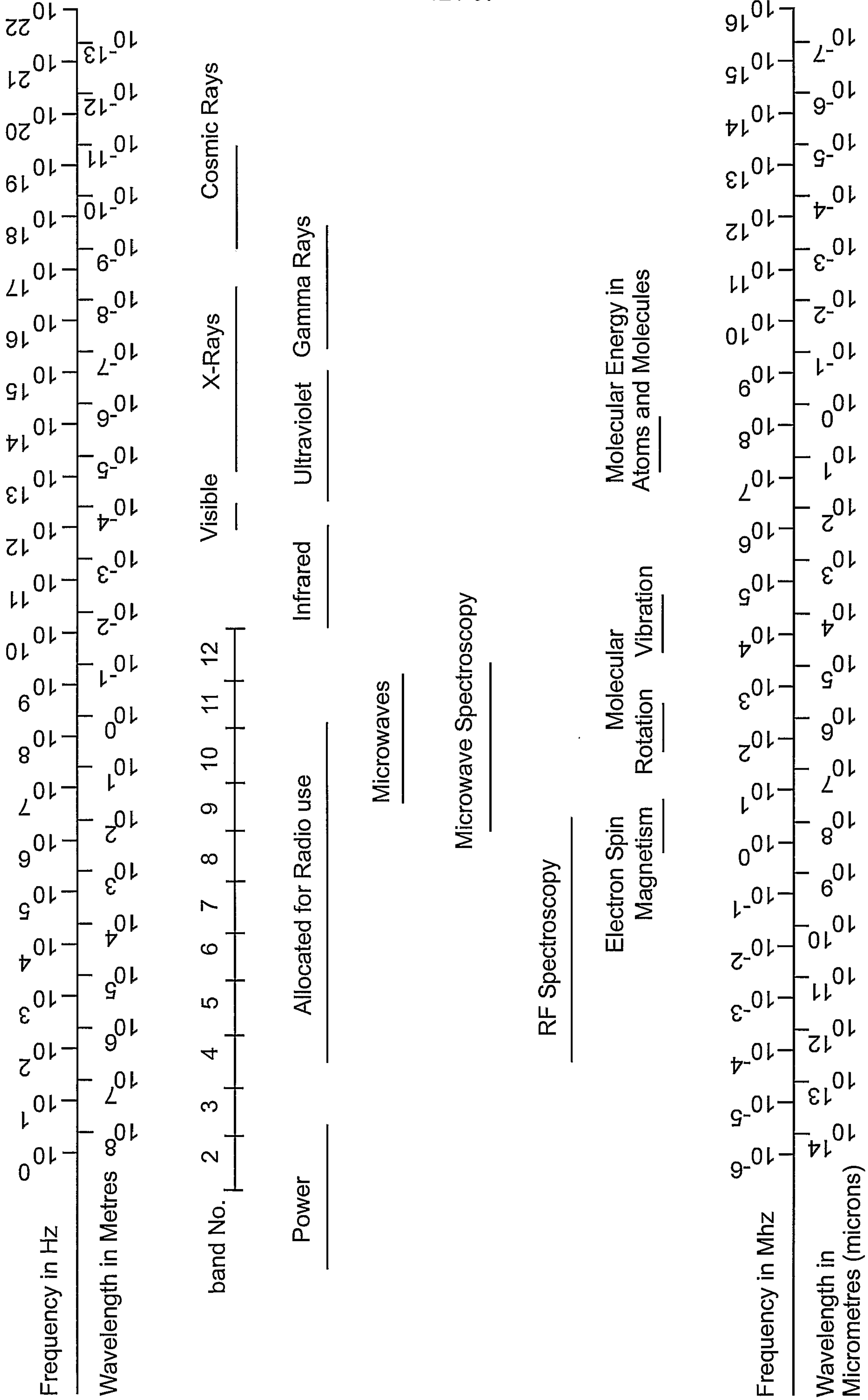
Radar Frequency Allocations for Remote Sensing (Ghz)
(All are shared with other services)

1.215-1.300, 3.1-3.3, 5.25-5.35, 8.55-8.65
9.50-9.80, 13.4-14.0, 17.2-17.3, 24.05-24.25
35.5-35.6, 78.0-79.0

Examples of other Allocations

Radar altimeter	4.2-4.4
Dopplar navigator	8.8, 13.25-13.4
Meteorological radar	5.6-5.65, 9.3-9.5
Coastal radar	5.35-5.65, 9.0-9.2, 10.0-10.55
Ship radar	5.46-5.47, 9.3-9.5, 14-14.3 24.25-25.25, 31.8-33.4

Fig.11.



The electromagnetic spectrum. The horizontal lines indicate the approximate spectral ranges of various physical phenomena and practical applications

Fig 12

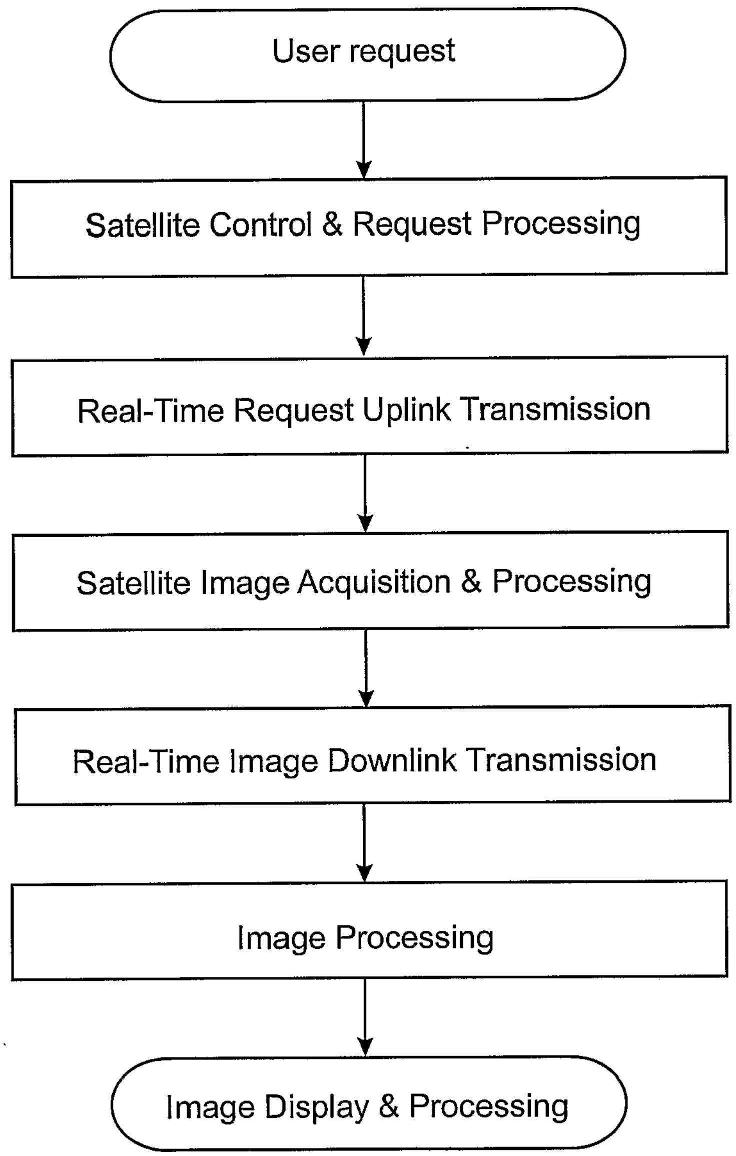

User request
Satellite Control & Request Processing
Real-Time Request Uplink Transmission
Satellite Image Acquisition & Processing
Real-Time Image Downlink Transmission
Image Processing
Image Display & Processing

Fig 13

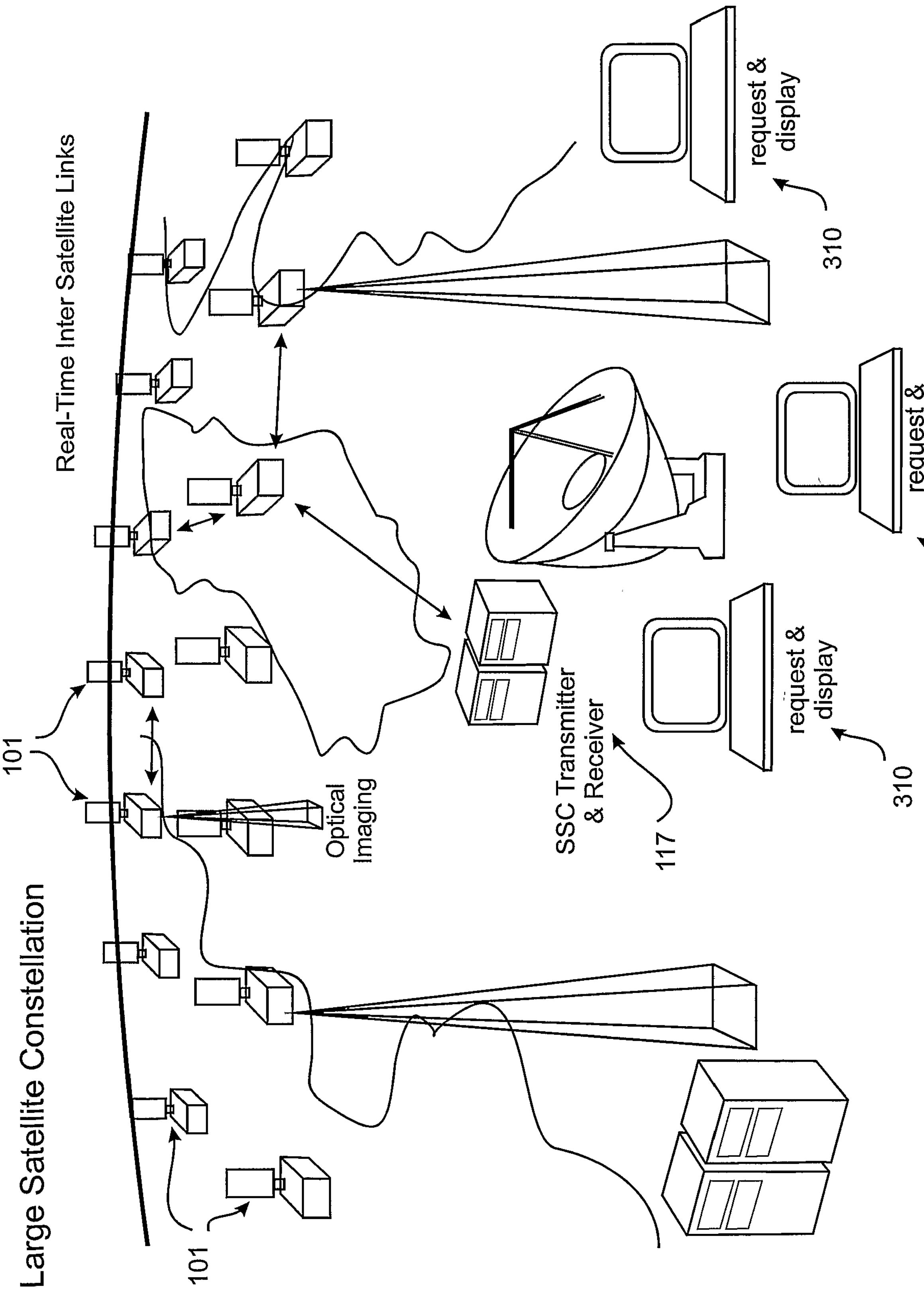

Large Satellite Constellation
Real-Time Inter Satellite Links
101
101
Optical Imaging
SSC Transmitter & Receiver
117
request & display
request & display
request & display
310
310
310

Fig 14

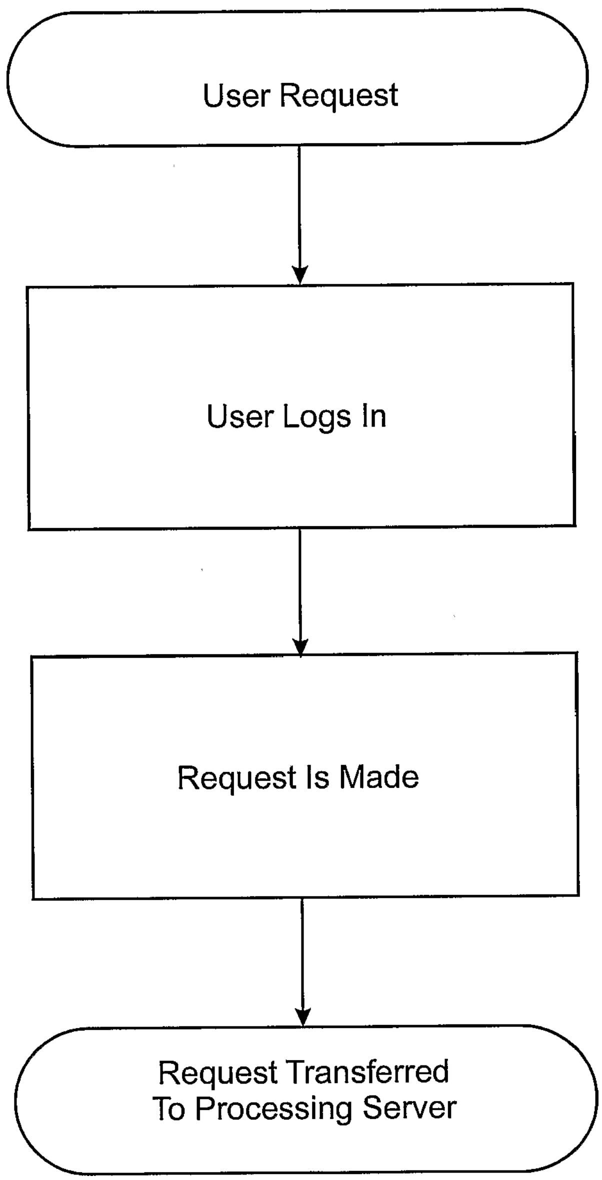

User Request
User Logs In
Request Is Made
Request Transferred
To Processing Server

Fig 15

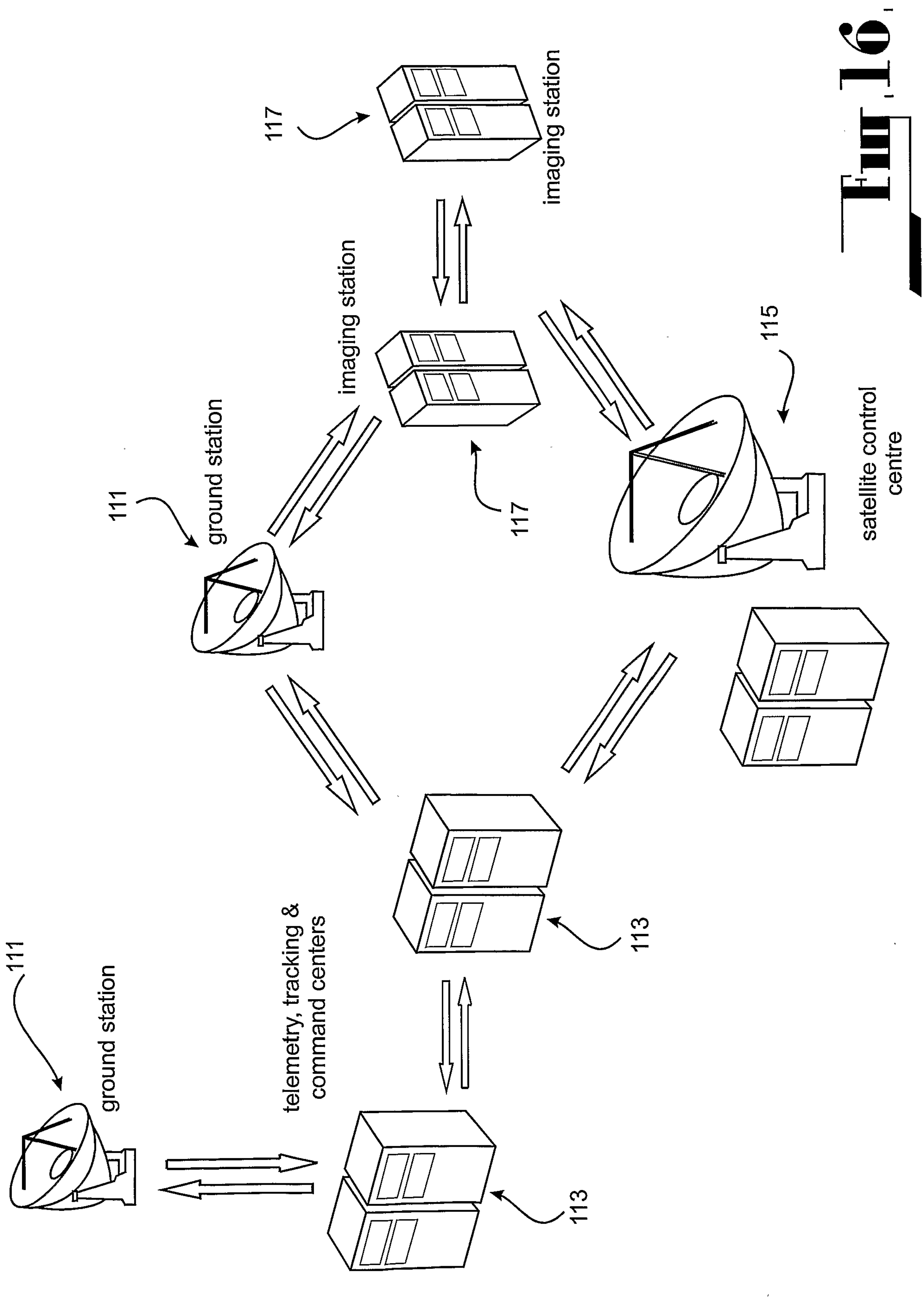

111
ground station
telemetry, tracking &
command centers
113
113
111
ground station
imaging station
117
117
imaging station
115
satellite control
centre

Fig. 16

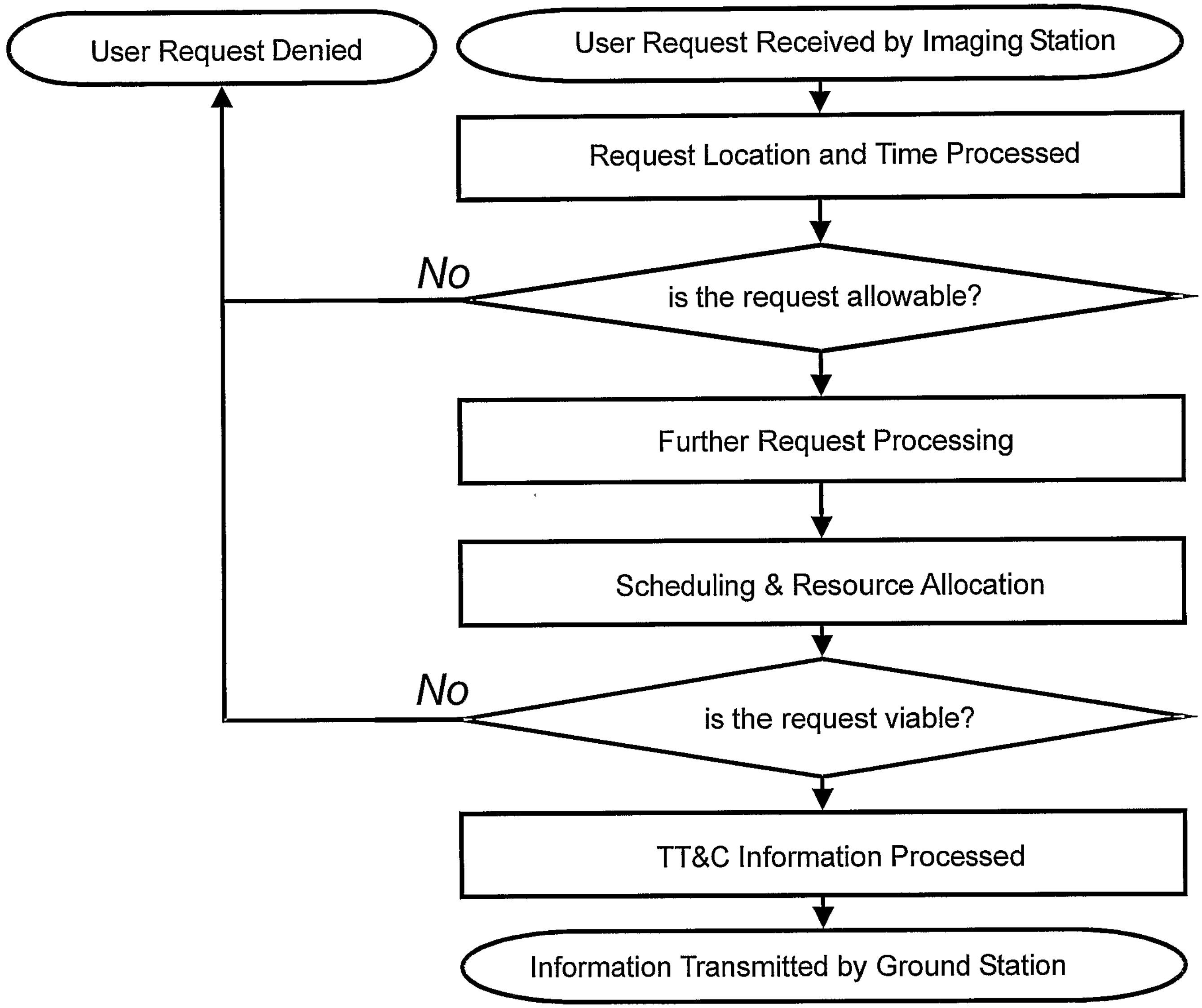

User Request Denied
User Request Received by Imaging Station
Request Location and Time Processed
No
is the request allowable?
Further Request Processing
Scheduling & Resource Allocation
No
is the request viable?
TT&C Information Processed
Information Transmitted by Ground Station

Fig 17

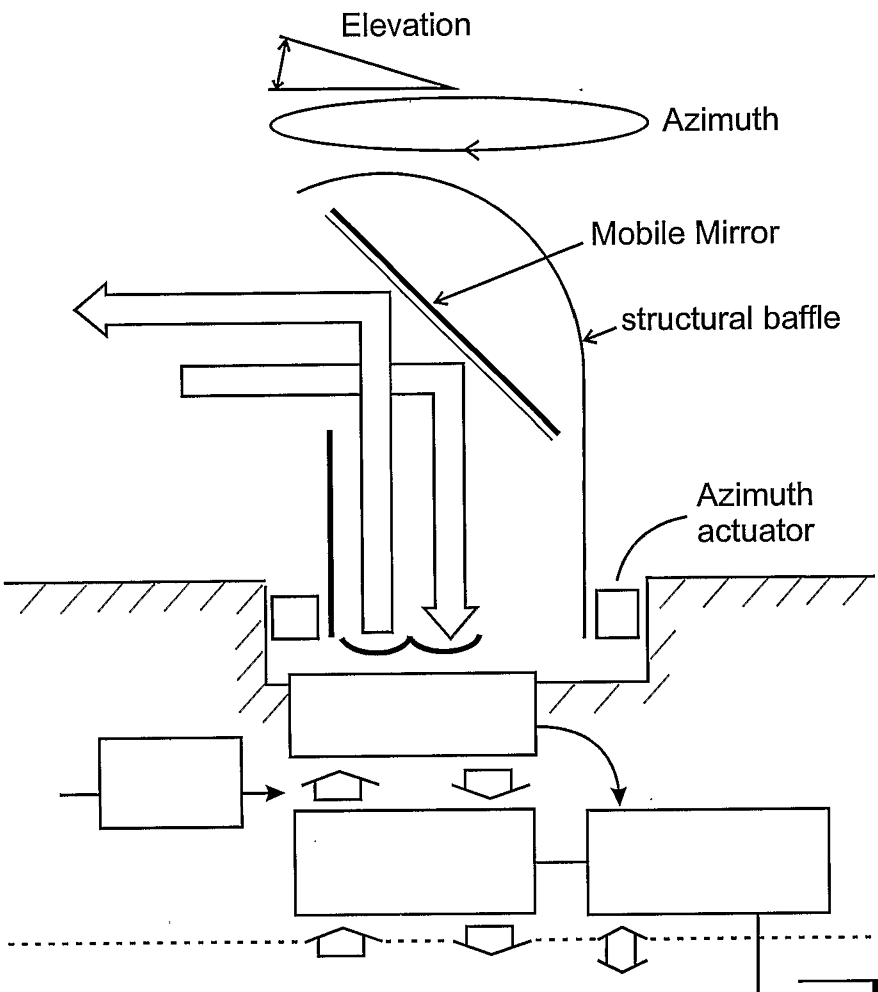

Elevation
Azimuth
Mobile Mirror
structural baffle
Azimuth
actuator

Fig. 18

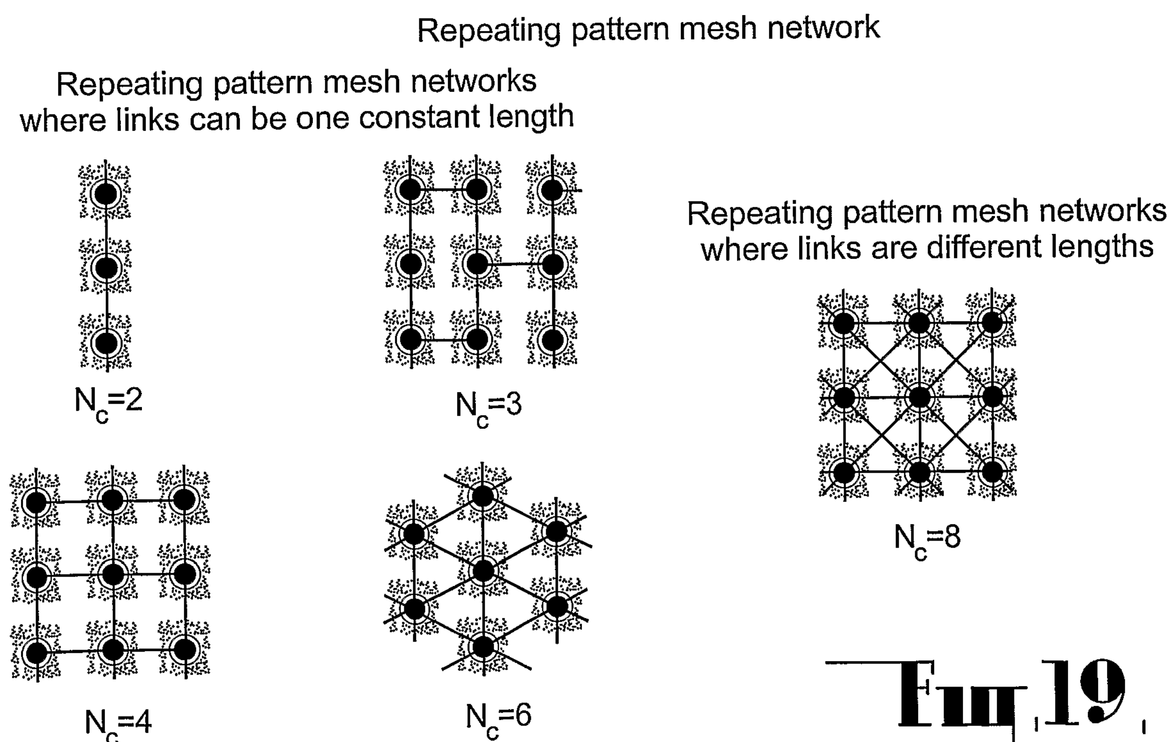

Repeating pattern mesh network
Repeating pattern mesh networks
where links can be one constant length
N_c=2
N_c=3
N_c=4
N_c=6
Repeating pattern mesh networks
where links are different lengths
N_c=8

Fig. 19

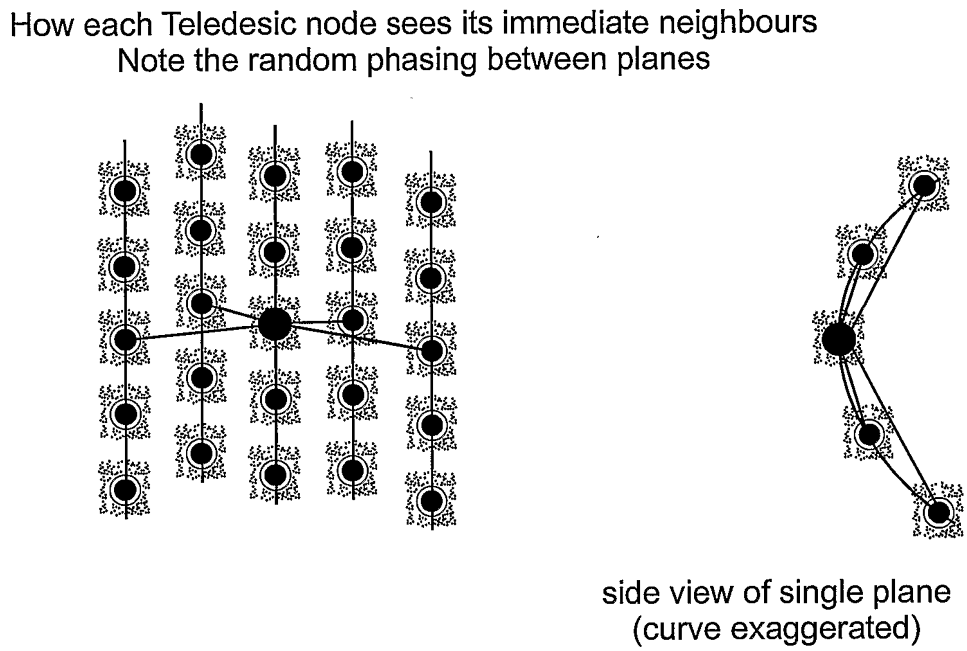

How each Teledesic node sees its immediate neighbours
Note the random phasing between planes
side view of single plane
(curve exaggerated)

Fig 20

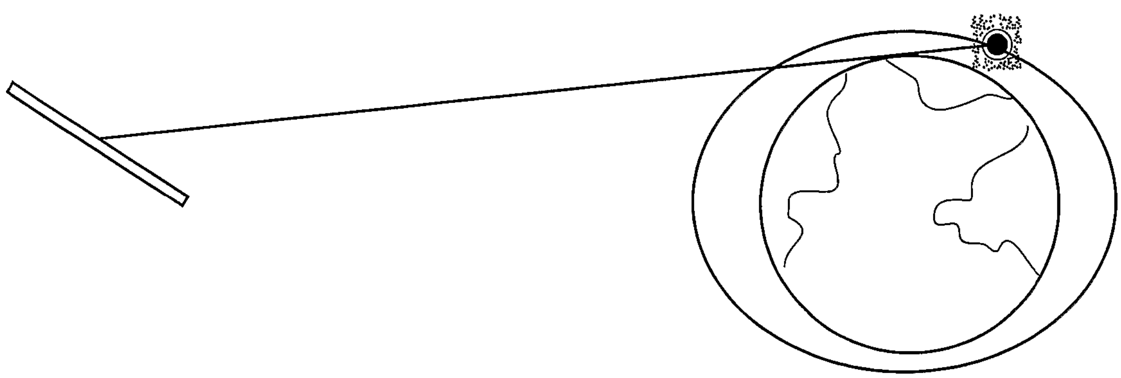


Fig 22

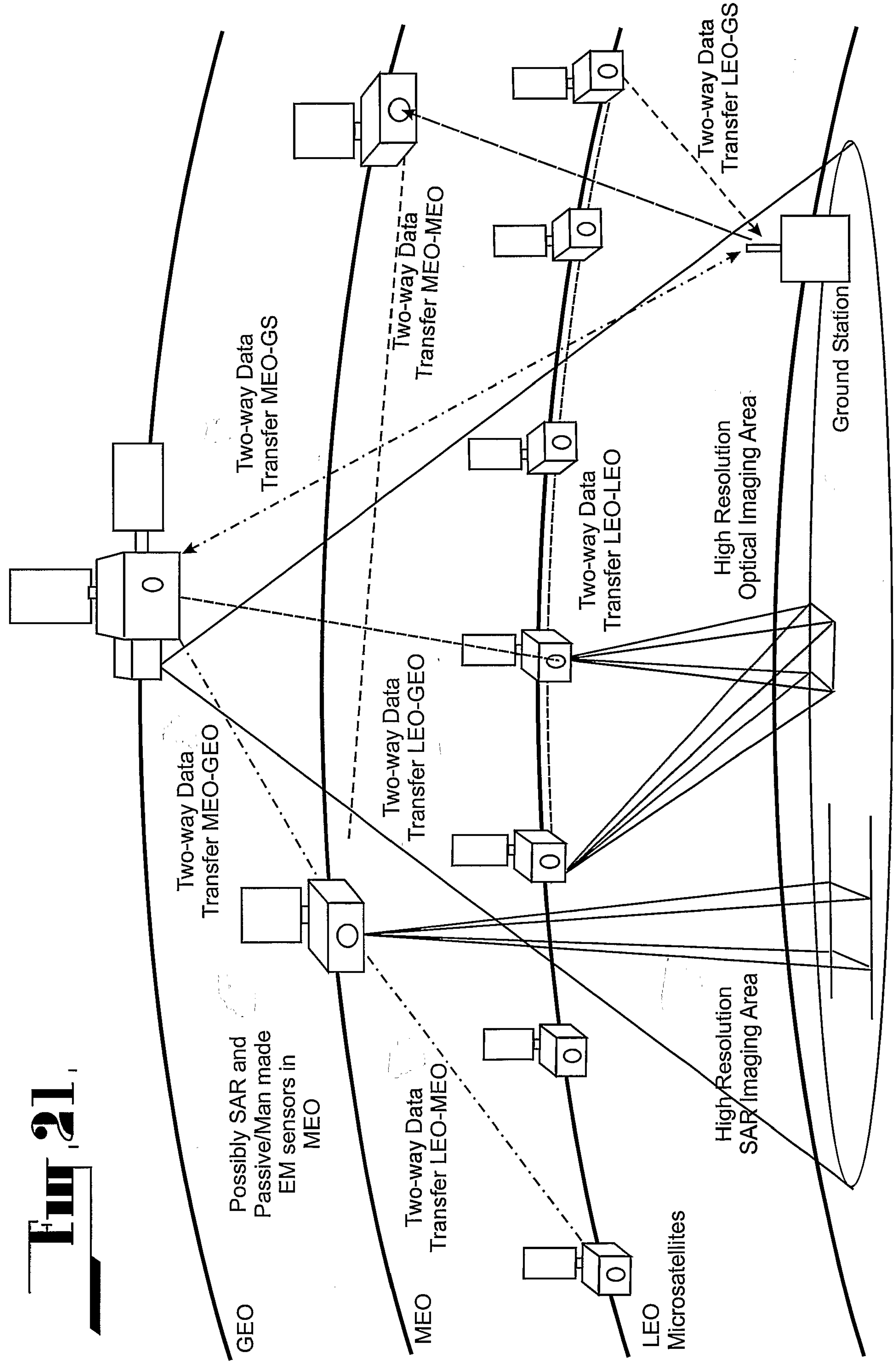

GEO
MEO
LEO
Microsatellites
Possibly SAR and
Passive/Man made
EM sensors in
MEO
Two-way Data
Transfer LEO-MEO
Two-way Data
Transfer MEO-GEO
Two-way Data
Transfer LEO-GEO
Two-way Data
Transfer MEO-GS
Two-way Data
Transfer MEO-MEO
Two-way Data
Transfer LEO-LEO
Two-way Data
Transfer LEO-GS
High Resolution
SAR Imaging Area
High Resolution
Optical Imaging Area
Ground Station

Fig 21

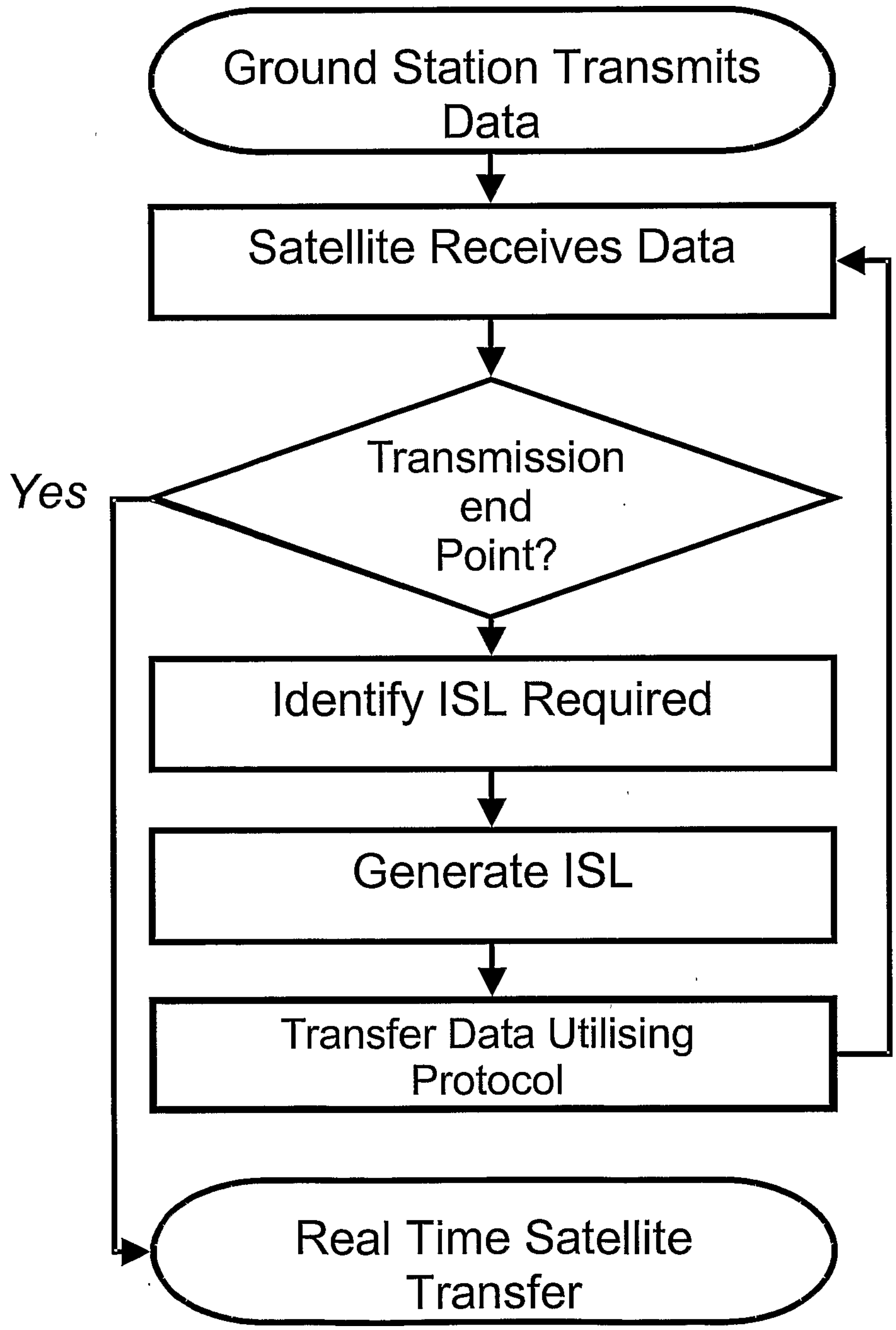

Ground Station Transmits Data
Satellite Receives Data
Yes
Transmission end Point?
Identify ISL Required
Generate ISL
Transfer Data Utilising Protocol
Real Time Satellite Transfer

Fig 23

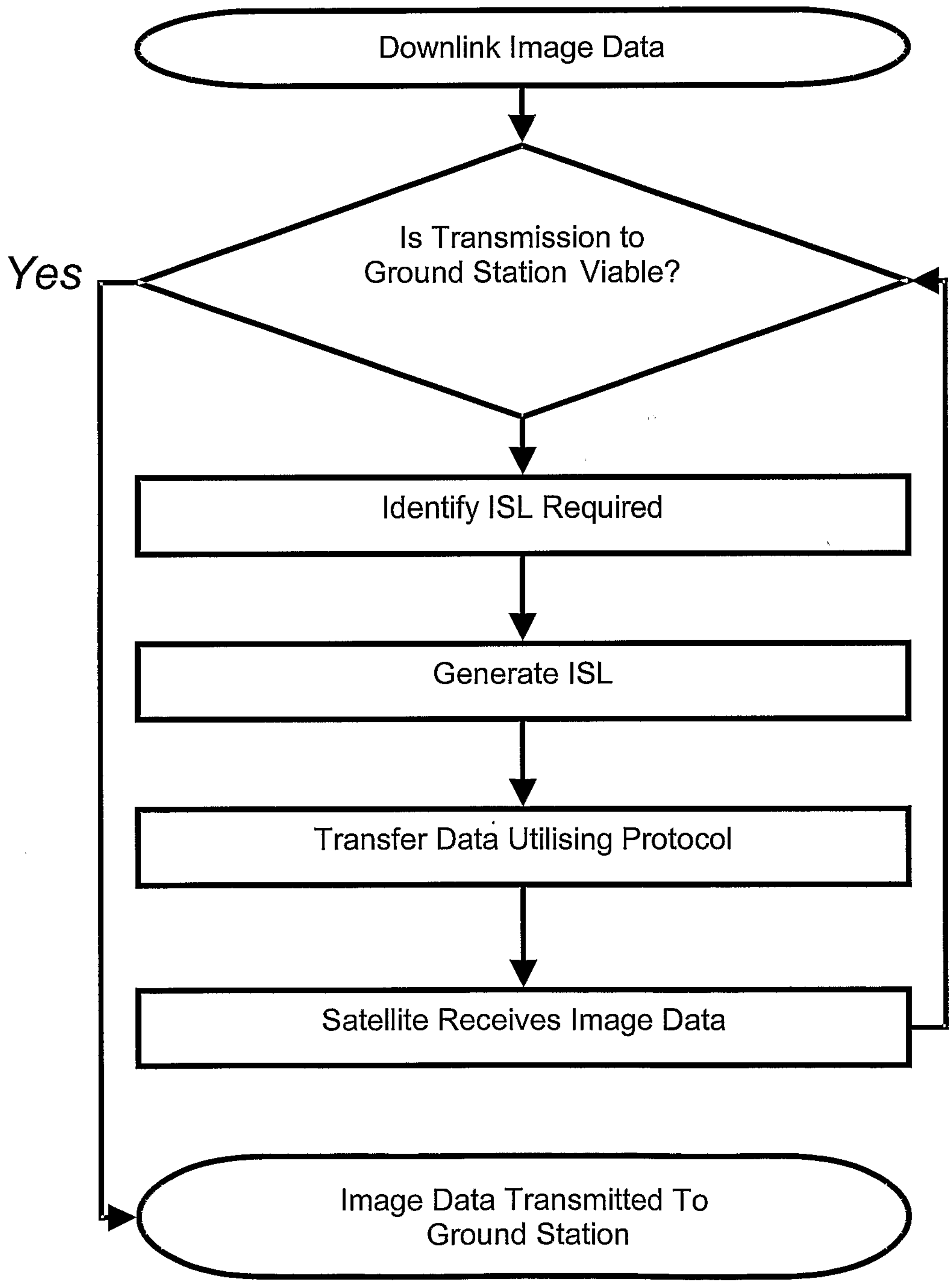

Downlink Image Data
Is Transmission to Ground Station Viable?
Yes
Identify ISL Required
Generate ISL
Transfer Data Utilising Protocol
Satellite Receives Image Data
Image Data Transmitted To Ground Station

Fig 24

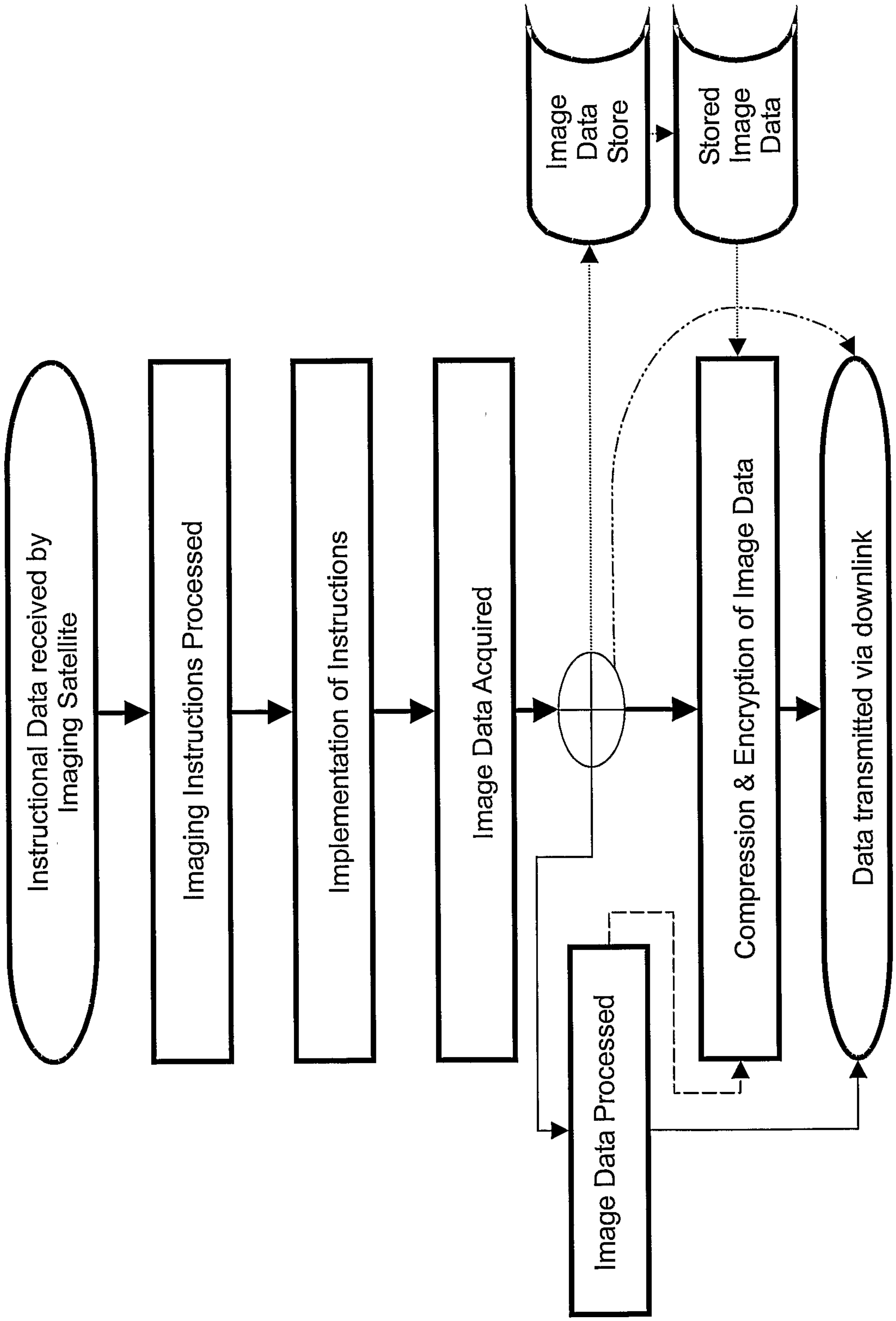

Instructional Data received by Imaging Satellite
Imaging Instructions Processed
Implementation of Instructions
Image Data Acquired
Image Data Store
Stored Image Data
Image Data Processed
Compression & Encryption of Image Data
Data transmitted via downlink

Fig 25

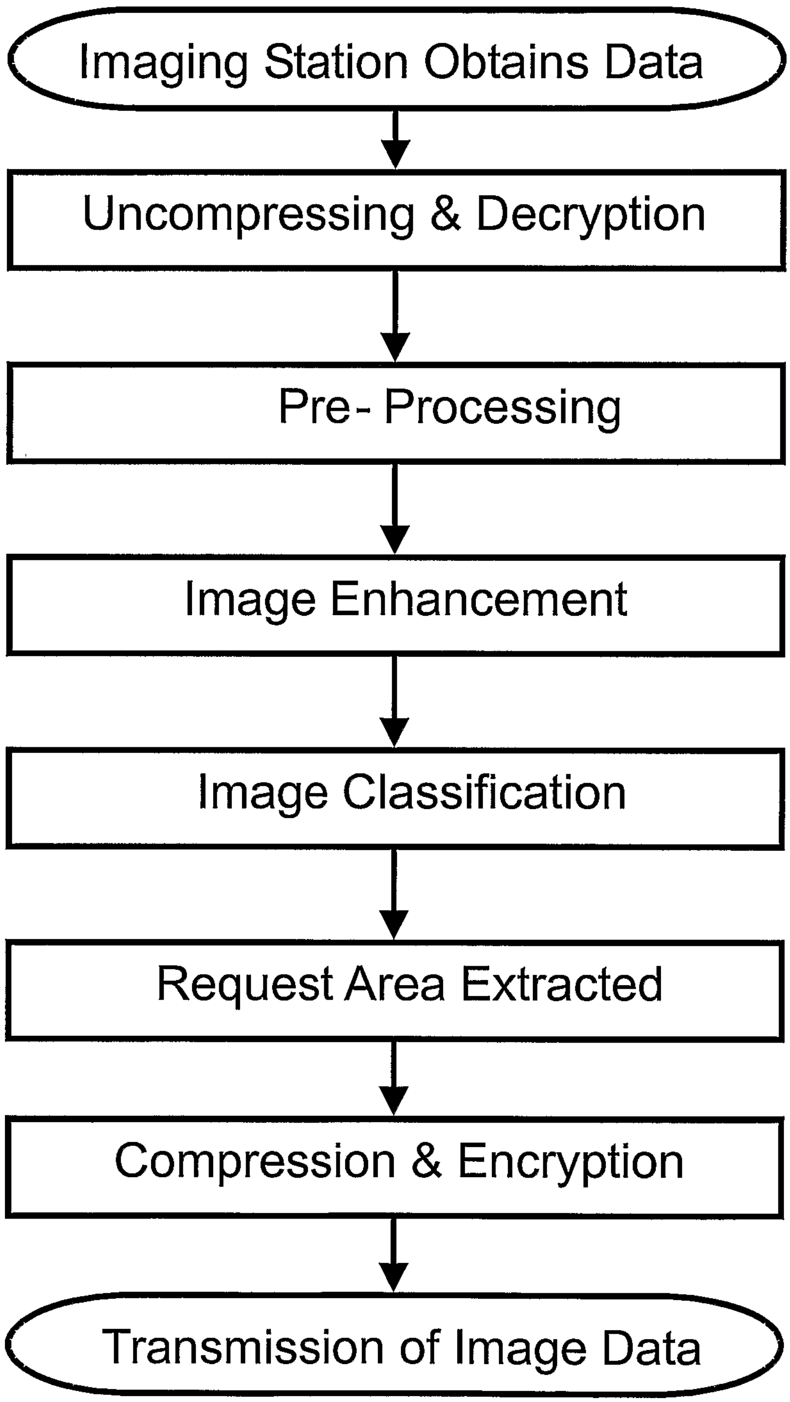

Imaging Station Obtains Data
Uncompressing & Decryption
Pre- Processing
Image Enhancement
Image Classification
Request Area Extracted
Compression & Encryption
Transmission of Image Data

Fig 26

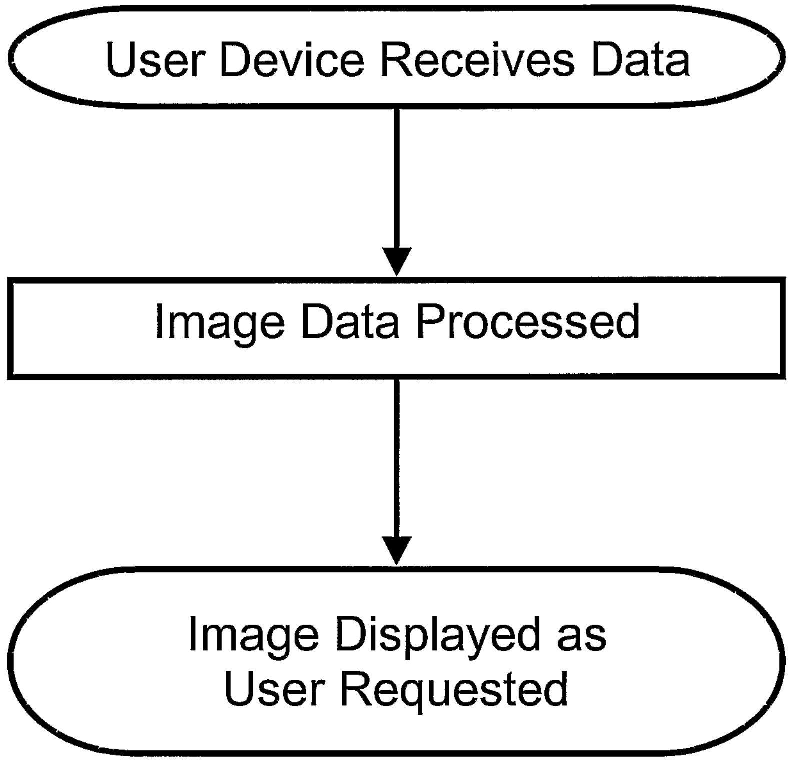

User Device Receives Data
Image Data Processed
Image Displayed as
User Requested

Fig 27

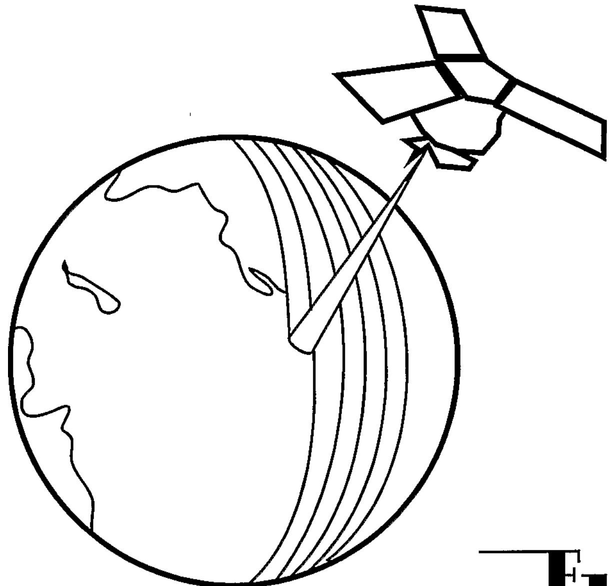


Fig 28

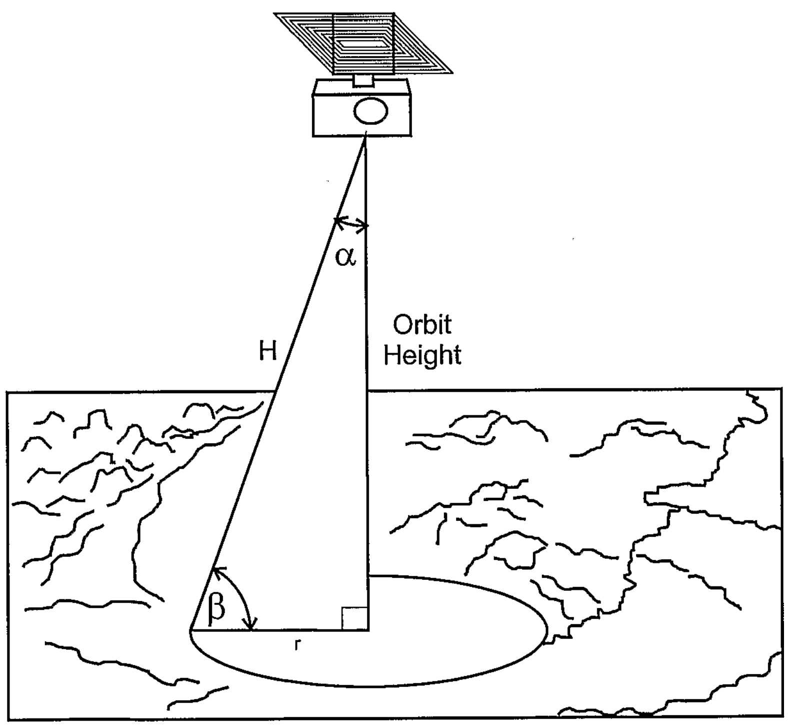


Fig 29

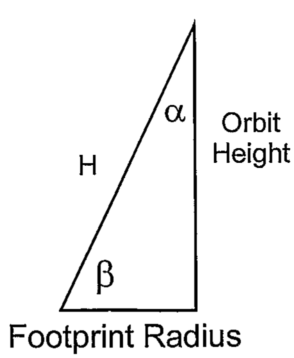
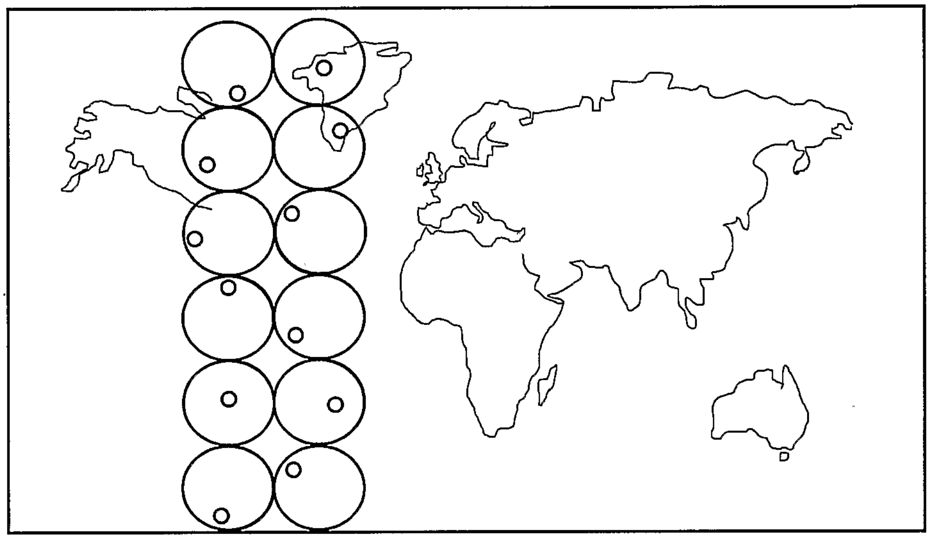


Fig 30


a

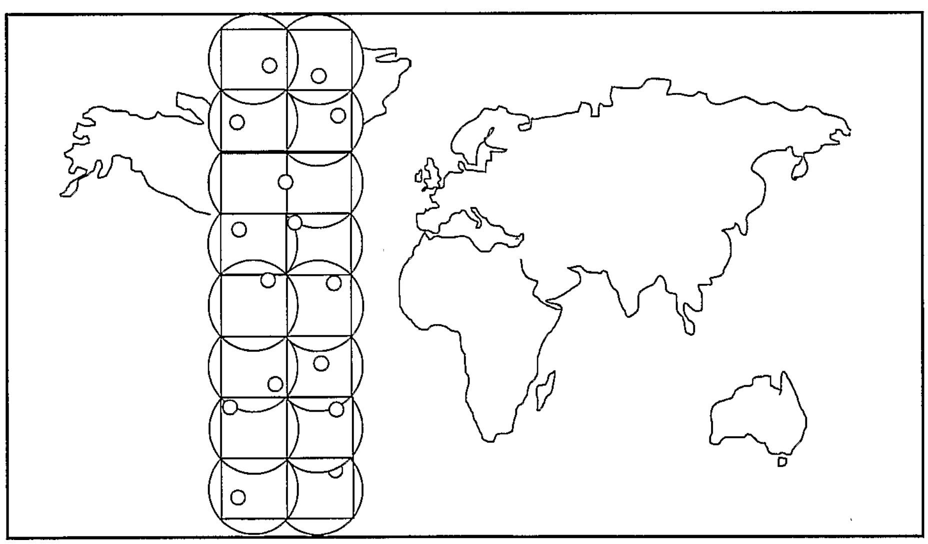

b

Fig 31

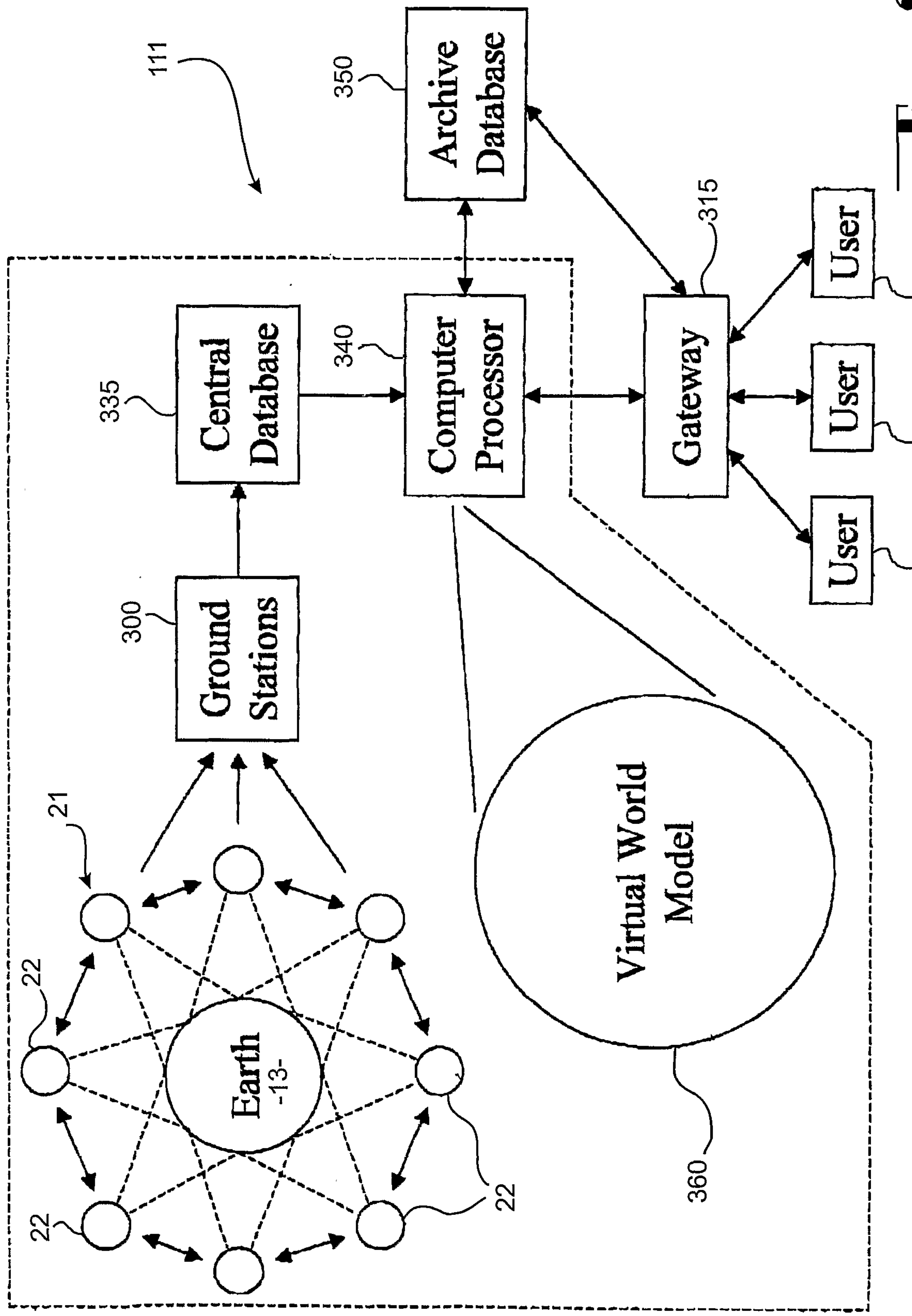

111
350
Archive Database
335
Central Database
340
Computer Processor
315
Gateway
User
User
User
310
310
310
300
Ground Stations
21
22
22
22
22
Earth
-13-
Virtual World Model
360

Fig. 32

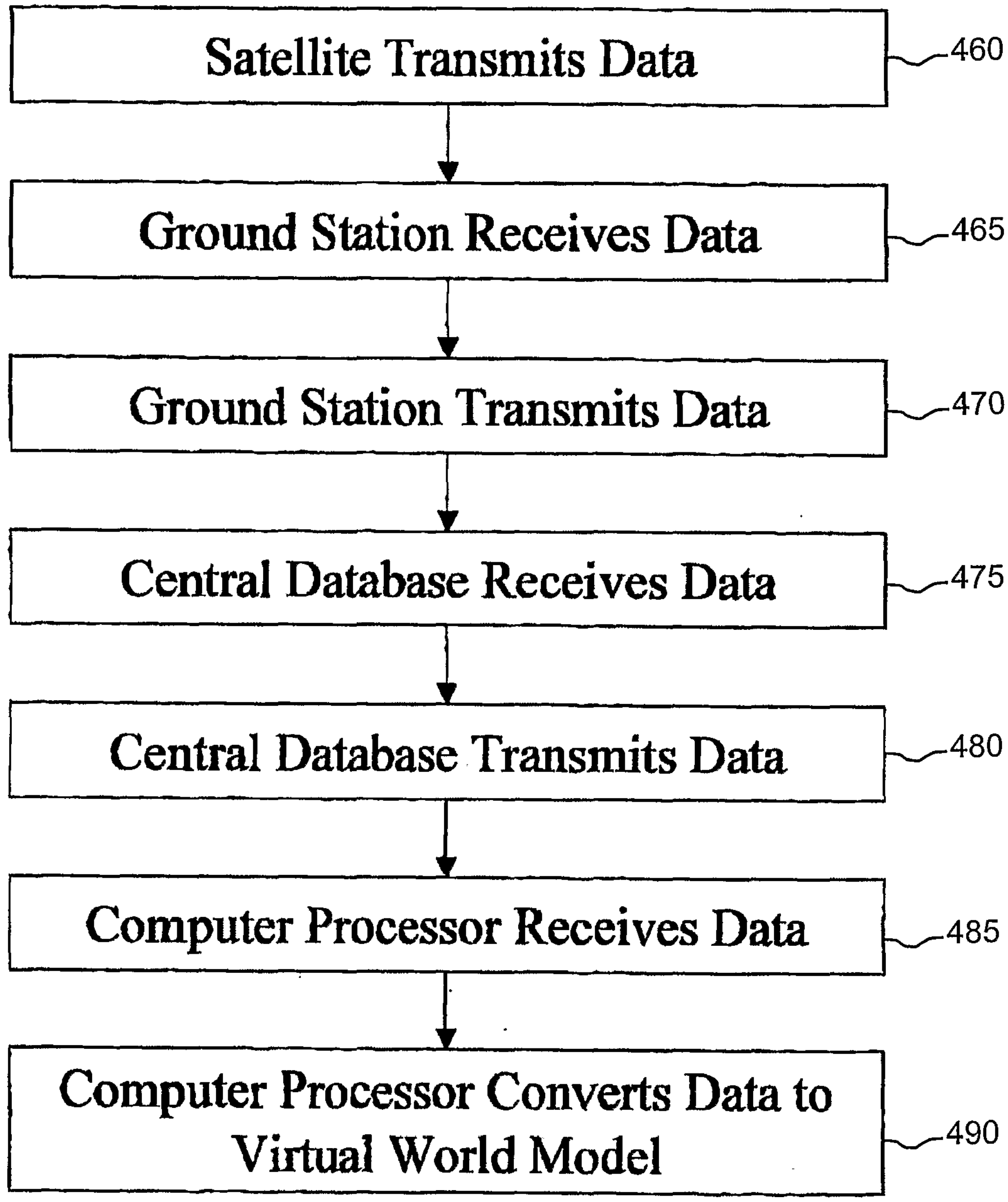

Satellite Transmits Data
460
Ground Station Receives Data
465
Ground Station Transmits Data
470
Central Database Receives Data
475
Central Database Transmits Data
480
Computer Processor Receives Data
485
Computer Processor Converts Data to Virtual World Model
490

Fig. 33

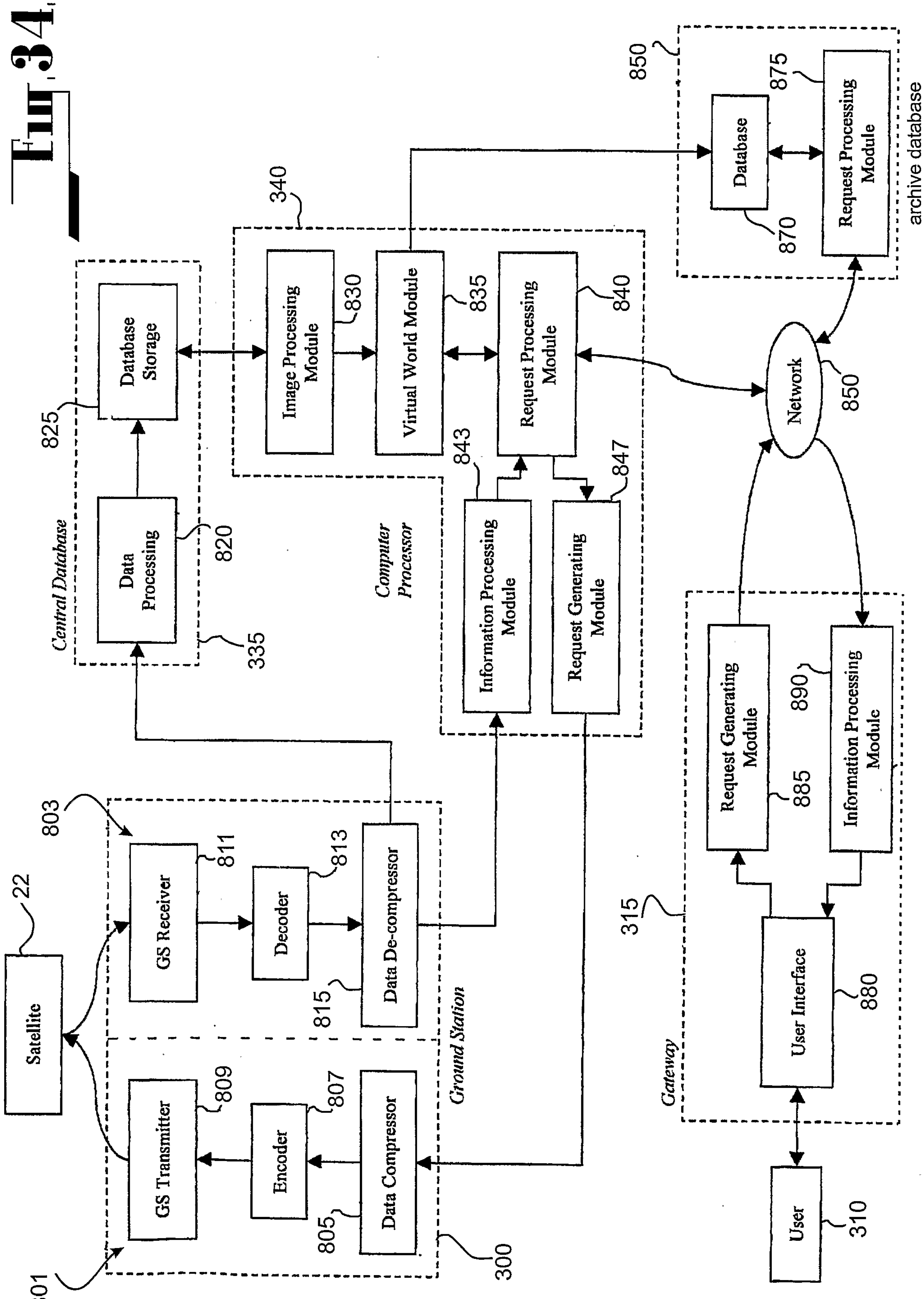

Satellite
22
801
803
GS Transmitter
809
Encoder
807
Data Compressor
805
GS Receiver
811
Decoder
813
Data De-compressor
815
Ground Station
300
Central Database
Data Processing
820
Database Storage
825
335
Computer Processor
Image Processing Module
830
Virtual World Module
835
Request Processing Module
840
340
Information Processing Module
843
Request Generating Module
847
Network
850
Database
870
Request Processing Module
875
850
archive database
Gateway
Request Generating Module
885
Information Processing Module
890
User Interface
880
315
User
310

Fig. 34

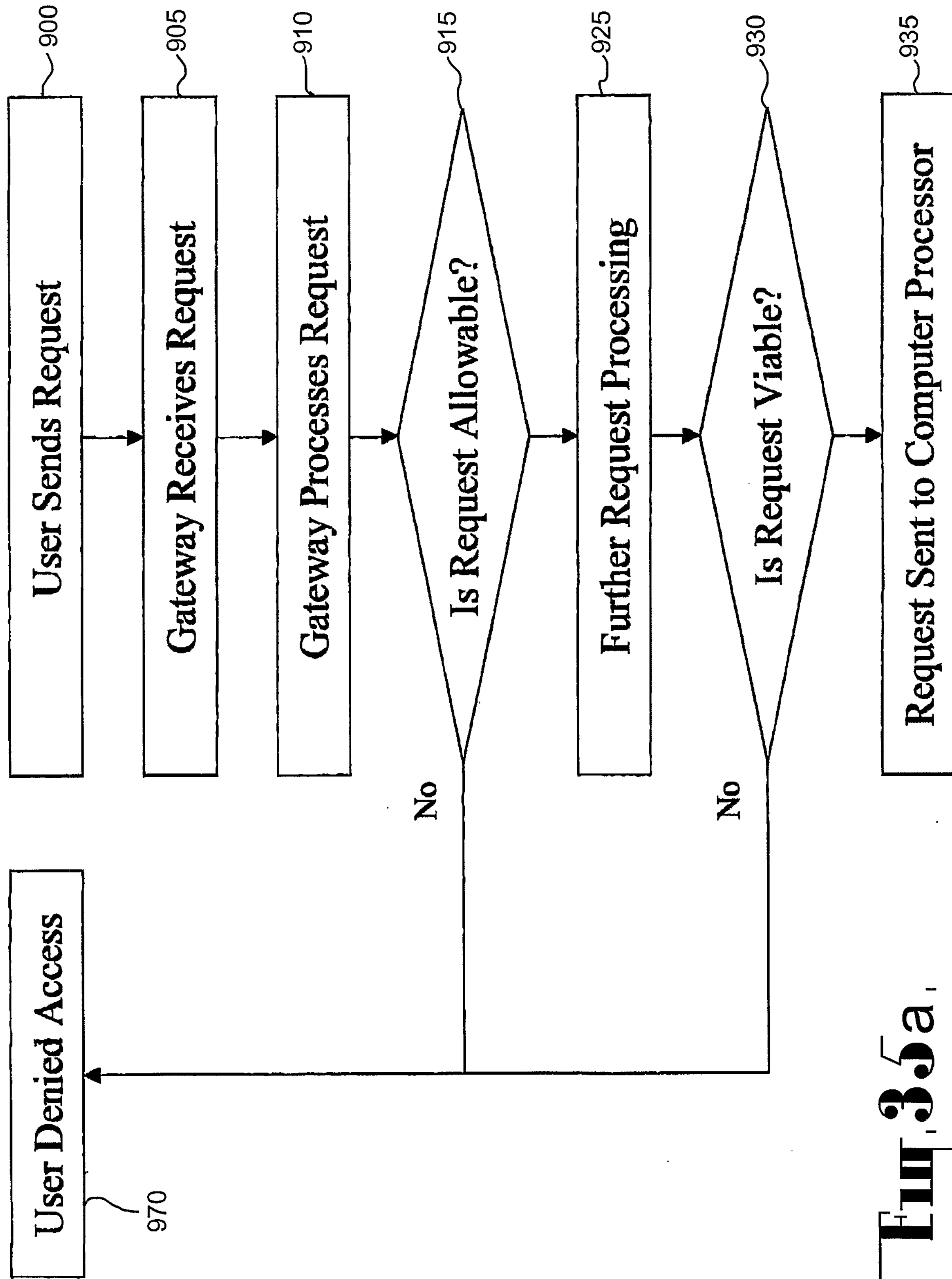

900
User Sends Request
905
Gateway Receives Request
910
Gateway Processes Request
915
Is Request Allowable?
No
925
Further Request Processing
930
Is Request Viable?
No
935
Request Sent to Computer Processor
970
User Denied Access

Fig. 35a

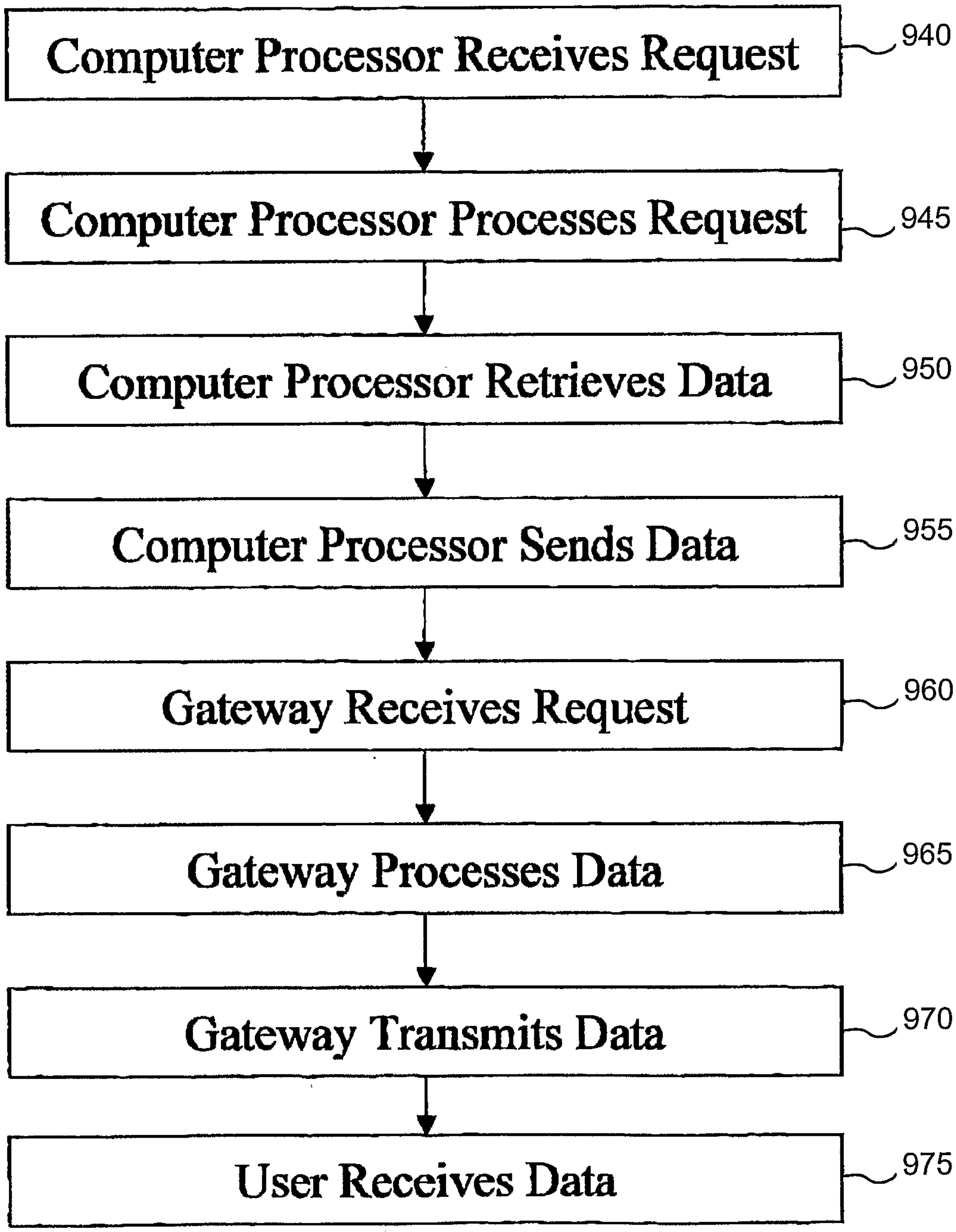

Computer Processor Receives Request
940
Computer Processor Processes Request
945
Computer Processor Retrieves Data
950
Computer Processor Sends Data
955
Gateway Receives Request
960
Gateway Processes Data
965
Gateway Transmits Data
970
User Receives Data
975

Fig. 35b

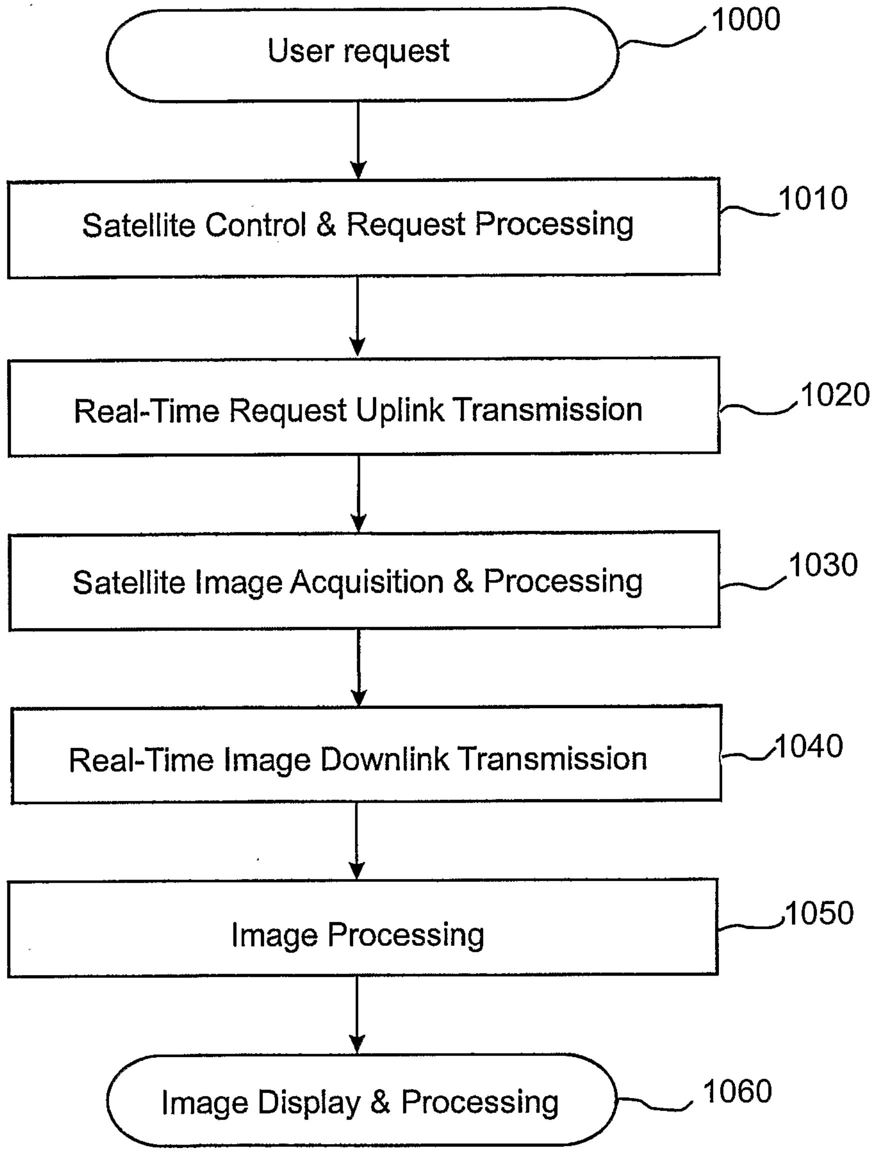

User request
1000
Satellite Control & Request Processing
1010
Real-Time Request Uplink Transmission
1020
Satellite Image Acquisition & Processing
1030
Real-Time Image Downlink Transmission
1040
Image Processing
1050
Image Display & Processing
1060

Fig. 36

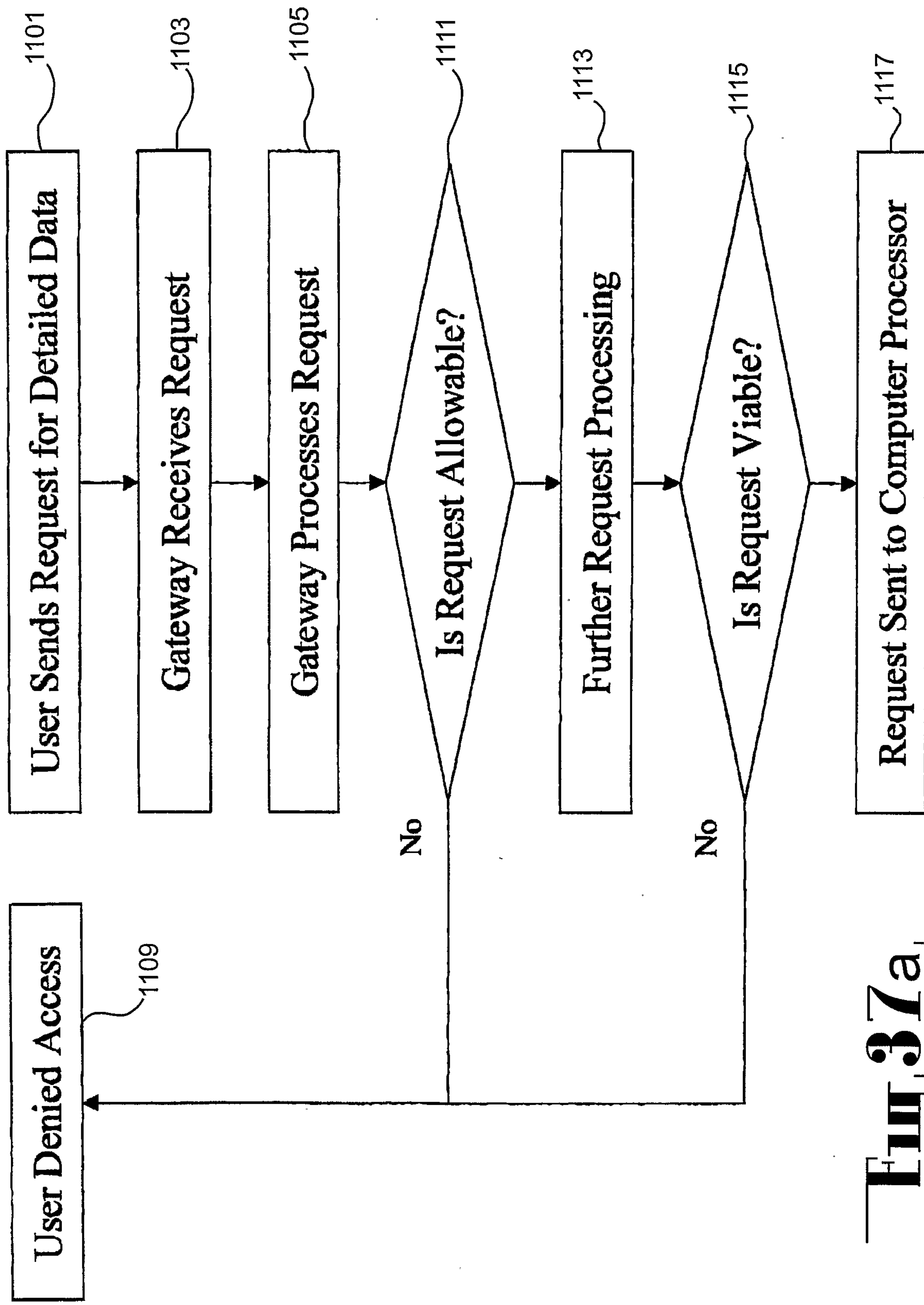

User Sends Request for Detailed Data
1101
Gateway Receives Request
1103
Gateway Processes Request
1105
Is Request Allowable?
1111
No
Further Request Processing
1113
Is Request Viable?
1115
No
Request Sent to Computer Processor
1117
User Denied Access
1109

Fig. 37a

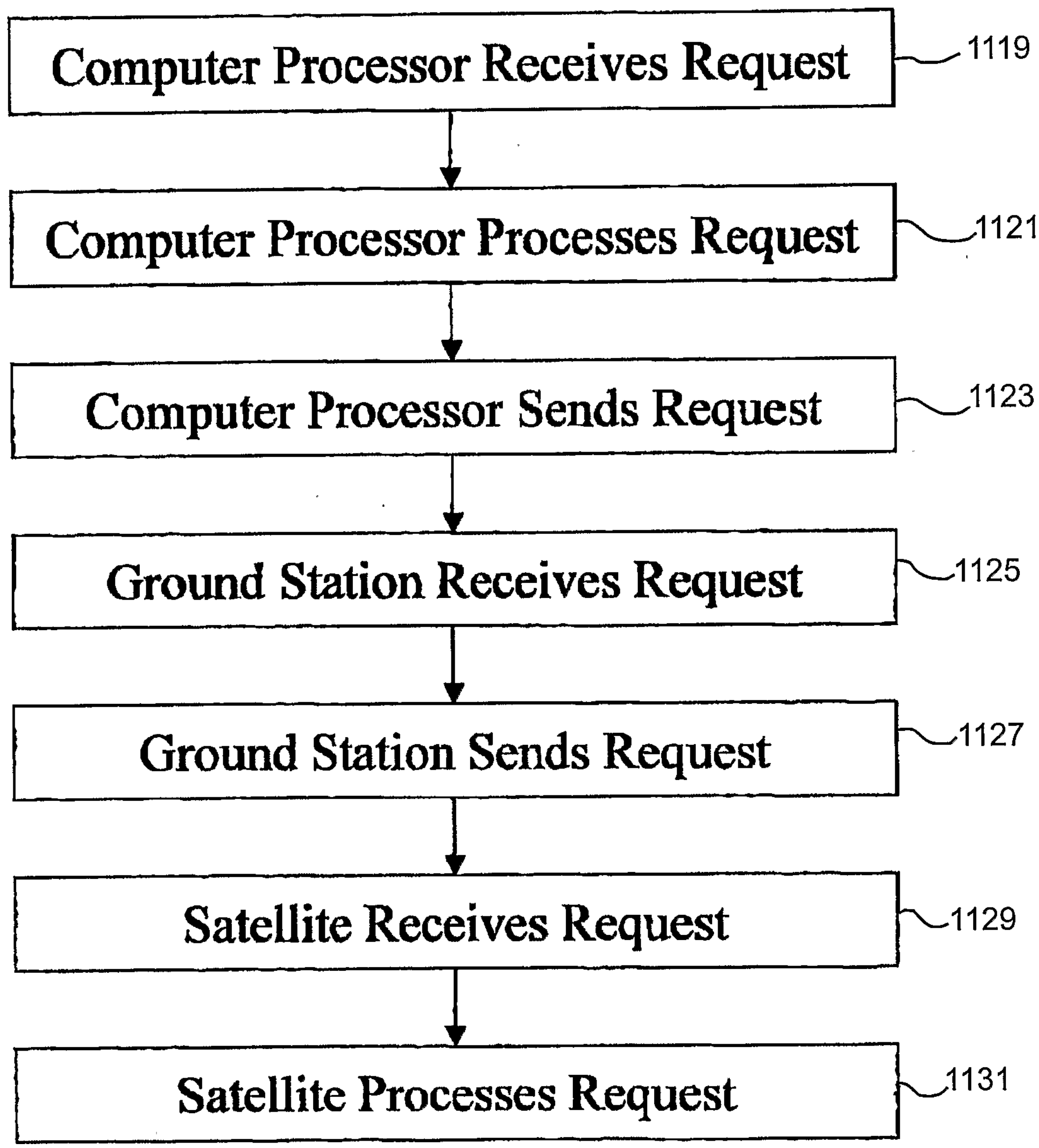

Computer Processor Receives Request
1119
Computer Processor Processes Request
1121
Computer Processor Sends Request
1123
Ground Station Receives Request
1125
Ground Station Sends Request
1127
Satellite Receives Request
1129
Satellite Processes Request
1131

Fig. 37b.

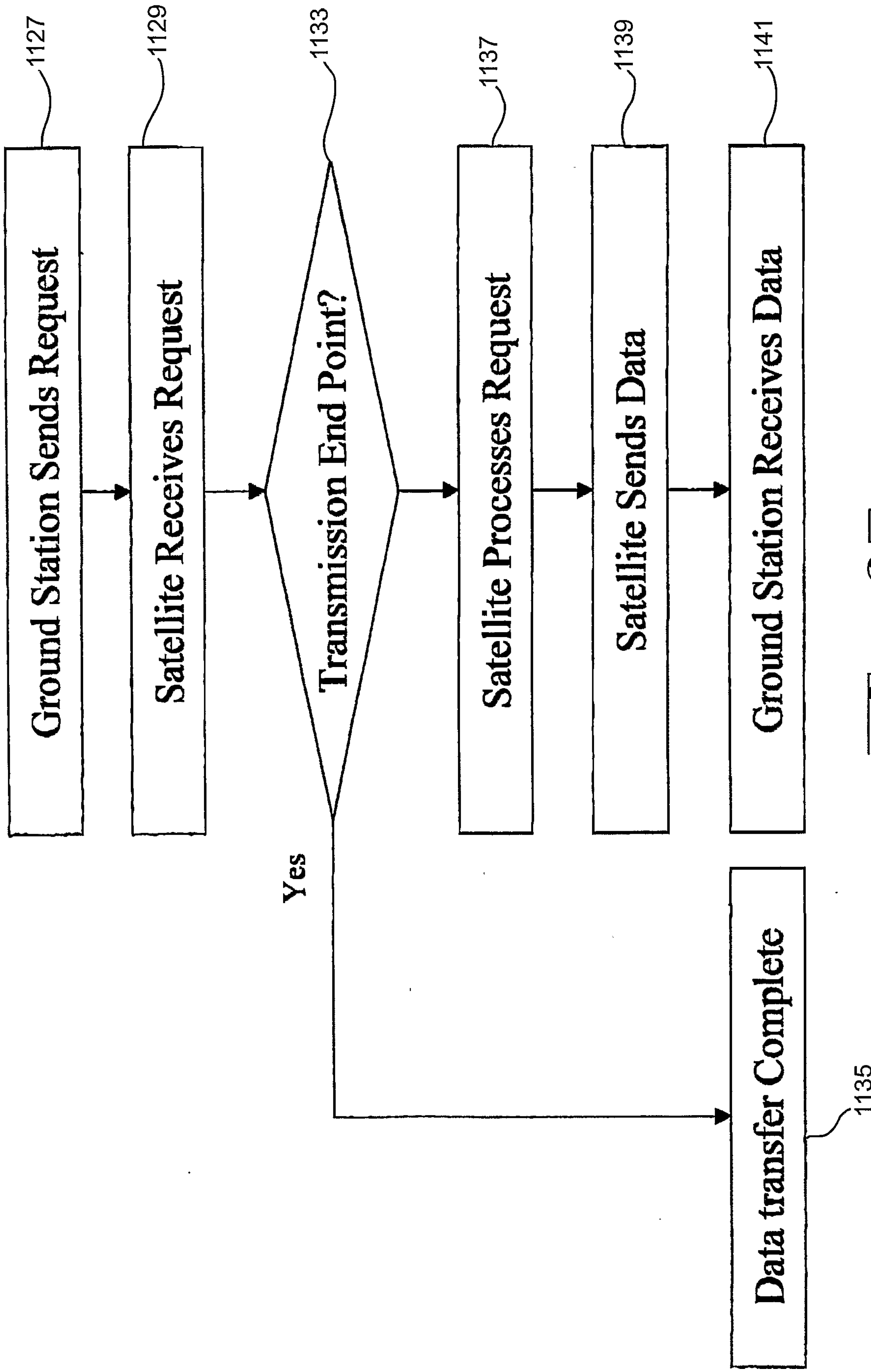

1127
Ground Station Sends Request
1129
Satellite Receives Request
1133
Transmission End Point?
Yes
1137
Satellite Processes Request
1139
Satellite Sends Data
1141
Ground Station Receives Data
1135
Data transfer Complete

Fig 37c

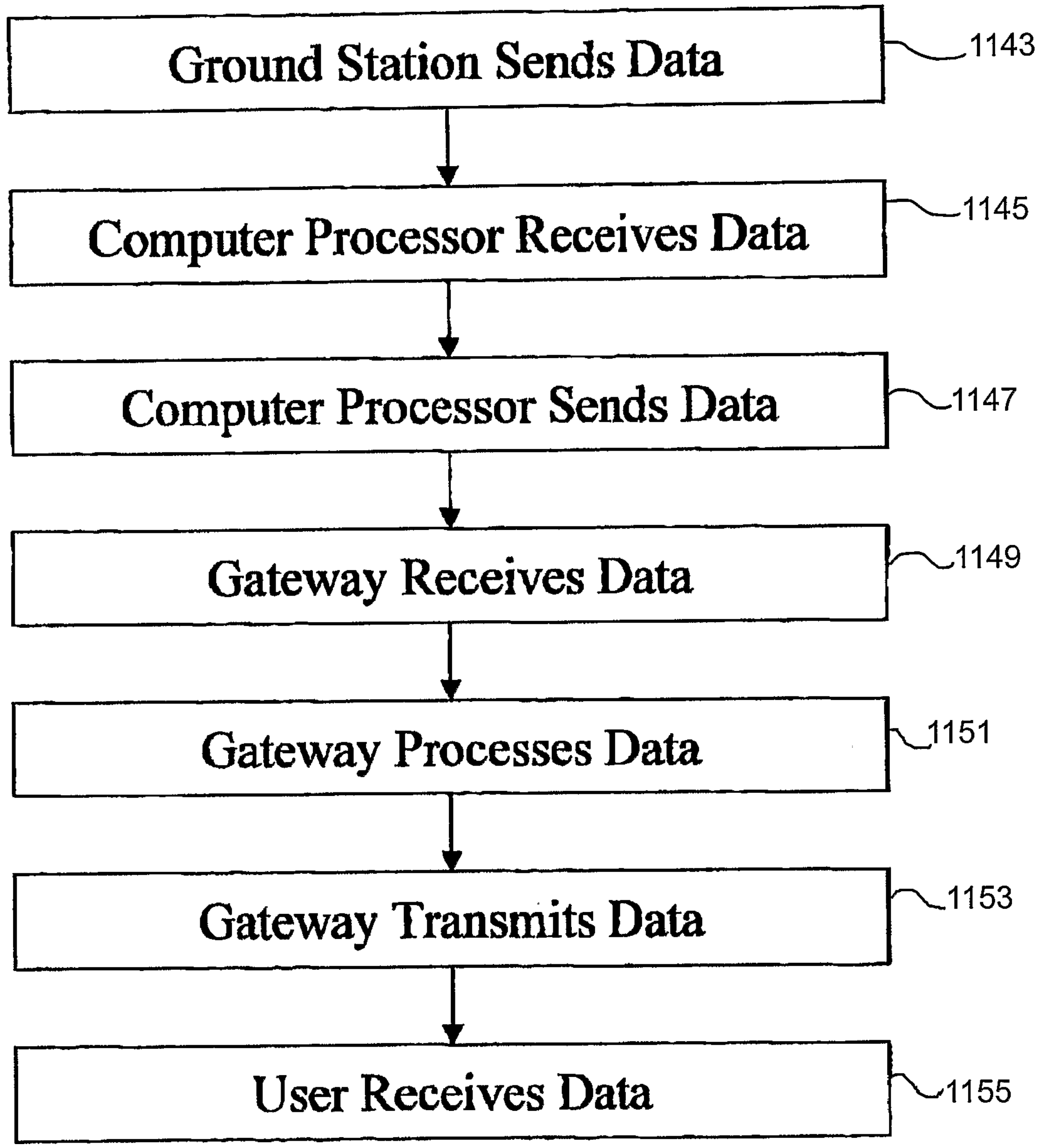

Ground Station Sends Data
1143
Computer Processor Receives Data
1145
Computer Processor Sends Data
1147
Gateway Receives Data
1149
Gateway Processes Data
1151
Gateway Transmits Data
1153
User Receives Data
1155

Fig. 37d

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU02/01565

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. [7]: G01C 11/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT: (platform, Satellite, LEO, MEO, air borne, air craft, image, map, survey, graph, real time footprint, overlap, earth, terrestrial, model, network, and similar terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01/68447 A2 (SKY CALYPSO INC) 20 September 2001 . See the abstract, pg. 12 ln. 22 - pg. 15 ;ln. 20..	1 - 10, 12, 15, 16, 19, 21 - 24, 26 - 41, and 57 - 62
A		11, 13, 14, 17, 18, 20, and 25
X	US 6271877 B1 (LECOMPTE) 7 August 2001 See abstract, col. 5 ln. 56 - col. 6 ln. 64, col. 6 ln. 17 - 42, 61 - 67, col. 16 ln. 17 - col. 17 ln. 66, and fig. 6.	1 - 12, 15, 19 - 24, 26 - 41, and 57 - 62
Y		16

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 January 2003	23 JAN 2003

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
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Facsimile No. (02) 6285 3929

Authorized officer

ROBERT BARTRAM

Telephone No : (02) 6283 2215

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 5883584 A (LANGEMANN et al) 16 March 1999. See col. 1 ln. 50 - 58, col. 2 ln. 29 - n65, col. 3 ln. 55 - 65	1 - 10, 12, 15, 16, 19, 21 - 24, 26 - 41, and 57 - 62 11, 13, 14, 17, 18, 20, and 25
Y A	US 5248979 A (ORME et al) 28 September 1993. See the abstract, col. 1 lns. 23 - 43, col. 2 lns. 11 - 33, col. 3 ln. 62 - col. 4 ln. 15, col. 4 ln. 30 - col. 5 ln. 45	16 1 - 15, 17 - 41, 57 - 62
Y	US 4814607 A (HOFMANN) 21 March 1989. See the abstract, and col. 2 ln. 3 - col. 3 ln. 51	1 - 41, 57 - 62
Y	US 4602257 A (GRISHAM) 22 July 1986. See the whole document.	1 - 41, 57 - 62
A	CA 2307006 A1 (VERITAS DGC INC) 30 October 2000. See whole document	1 - 41, 57 - 62
A	Patent abstracts of Japan , JP 11-027195 A (SONY CORP) 29 January 1999 See the abstract.	1 - 41, 57 - 62
A	WO 86/01592 A1 (HUGHES AIRCRAFT COMPANY) 13 March 1986. See the abstract, pg. 3 ln. 1 - pg. 4 ln. 16, pg. 4 ln. 27 - pg. 5 ln. 27, claims 1 and 3, and figs. 1 and 2.	1 - 41, 57 - 62
	Note: for the Y category document US 5248979 can be combined with US 6271877, and documents US 4602257 and US 4814607 are combined together.	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU02/01565

Box I Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos :

   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos :

   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos :

   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box II Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

   1 to 41, and 57 to 62.

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

Supplemental Box
(To be used when the space in any of Boxes I to VIII is not sufficient)

Continuation of Box No: II

The claims do not relate to one invention only (or to a group of inventions so linked as to form a single general inventive concept). In assessing whether there is more than one invention claimed, I have given consideration to those features which can be considered to be "special technical features". These are features which potentially distinguish the claimed combination of features from the prior art. Where different claims have different special technical features they define different inventions. I have found that there are different inventions as follows:

(1) Claims 1-41, and 57-60 are directed towards an imaging system for communicates image information in real time or near real time to a user wherein a large number of platform in non-geostationary earth orbits have one or more sensors that have an footprint that is adjacent and overlaps to adjacent platform sensor footprints. It is considered that an imaging system for communicates image information in real time or near real time to a user wherein a large number of platform in non-geostationary earth orbits have one or more sensors that have an footprint that is adjacent and overlaps to adjacent platform sensor footprints comprises a first "special technical feature".

(2) Claims 42-45 are directed towards an imaging system utilizing a large constellation of platforms collectively wherein the platforms include passive and active sensors. Each sensor is adapted to collect data from the earth's surface. Identification means indicates where data has been collected by said passive sensors and a comparison means determines if the active sensors is used to collect data. It is considered that an imaging system utilizing a large constellation of platforms collectively wherein the platforms include passive and active sensors. Each sensor is adapted to collect data from the earth's surface. Identification means indicates where data has been collected by said passive sensors and a comparison means determines if the active sensors is used to collect data comprises a second "special technical feature". There is no mention of non-geostationary orbit, the real or near real time, the overlapping footprint, or the communication of data to a user features of the first set of claims.

(3) Claims 46-56 are directed towards a system for collecting data from a constellation of platforms some or all of them having sensors, wherein a processing mean receives multiple sets of data from separate platforms and combining the sets of data to generate a representation of the earth. It is considered that a system for collecting data from a constellation of platforms some or all of them having sensors, wherein a processing mean receives multiple sets of data from separate platforms and combining the sets of data to generate a representation of the earth comprises a third "special technical feature". Again there is no mention of non-geostationary orbit, the real or near real time, the overlapping footprint, or the communication of data to a user features of the first set of claims.

Since the abovementioned groups of claims do not share any of the technical features identified, a technical relationship between the inventions does not exist. Accordingly the claims do not relate to one invention or to a single inventive concept, a priori.

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
WO	01/68447	AU	200140133				
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