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(54) UNIVERSAL SPACECRAFT ARCHITECTURE

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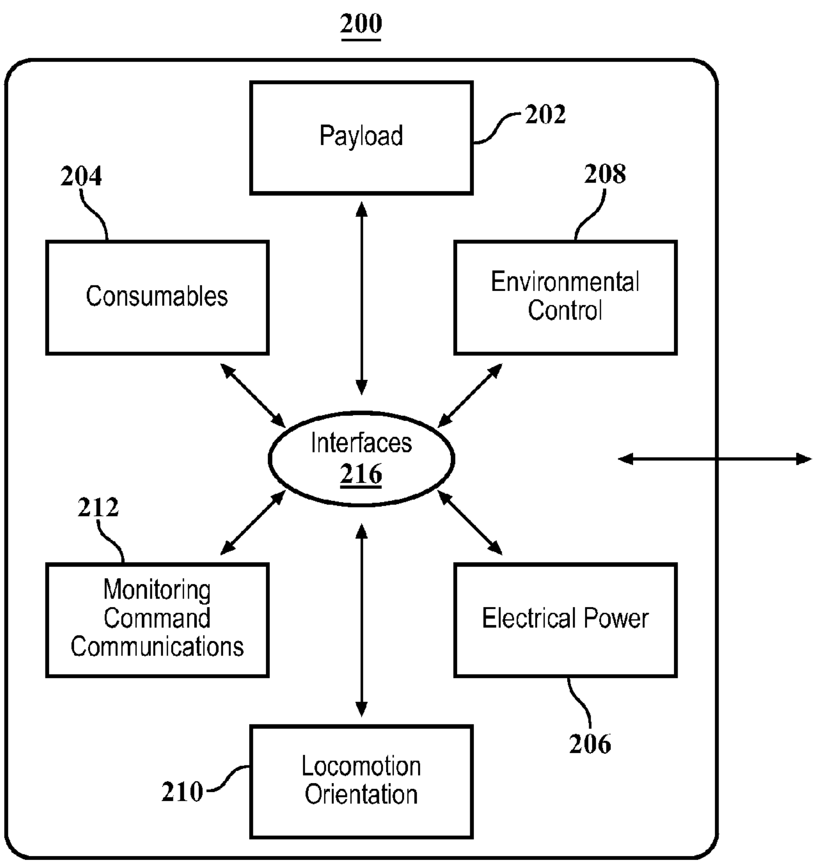
USPC **244/159.4**; 704/2; 29/428

(57) **ABSTRACT**

A system and method for assembling a spacecraft in orbit using orbiting modules. Each module has a function such as fuel, transport, communication and payload. A command and control system and logic assembles the modules for missions. After use the modules may be disassembled and parked in orbit. The assembly of modules for a mission is controlled by a logic that assesses the mission requirement, module status and capability and matches resources. The referenced command and control system and logic is used to maneuver vehicles and modules and controls missions. Communications between and among modules and signal sources are facilitated by a language protocol that has a library of commands and responses accessible by signals using divergent communications languages. The protocol also converts common programming language to a language compatible for use by a recipient module, logic or communication satellite or ground station.



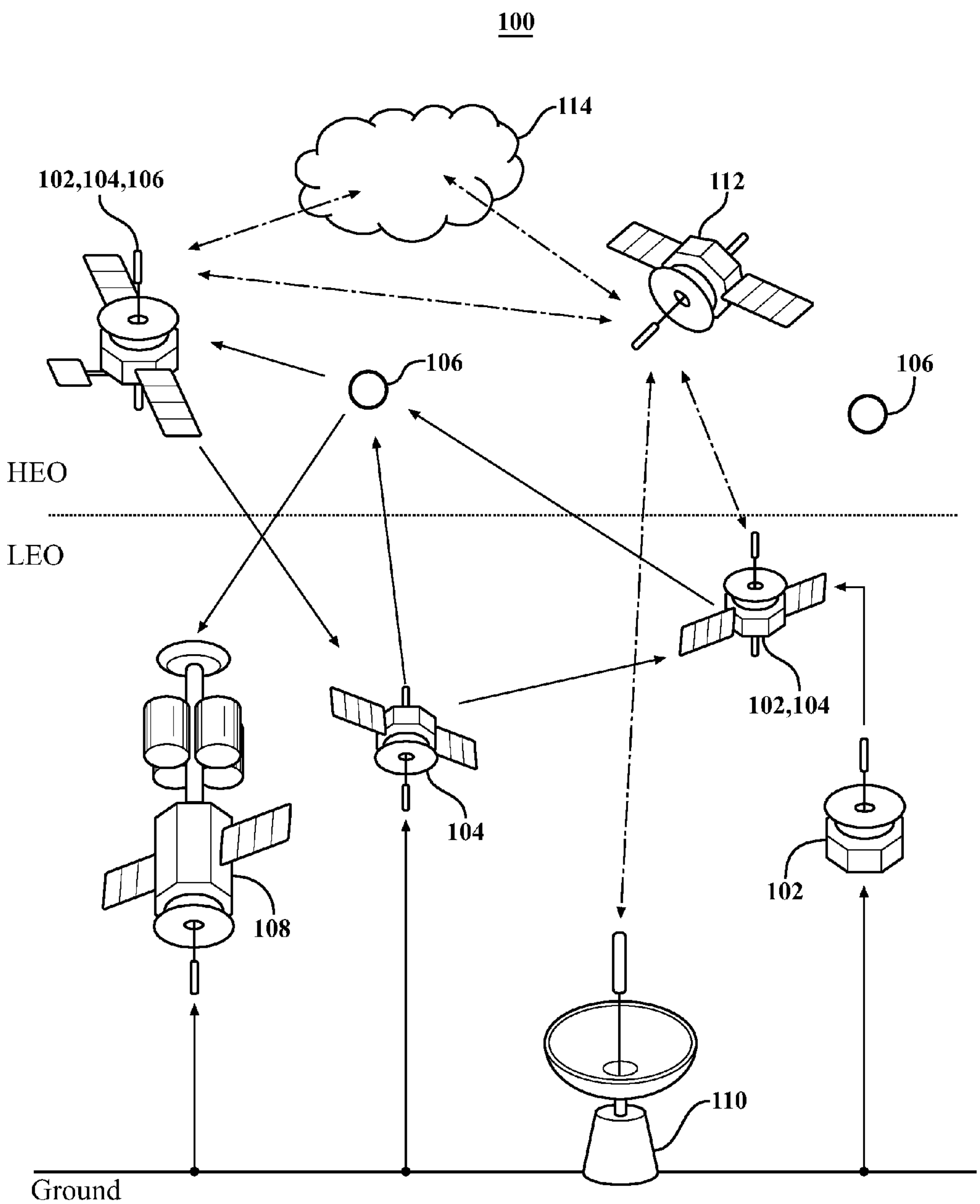

100
114
102,104,106
112
106
106
HEO
LEO
102,104
104
108
102
110
Ground

FIG. 1

FIG. 2

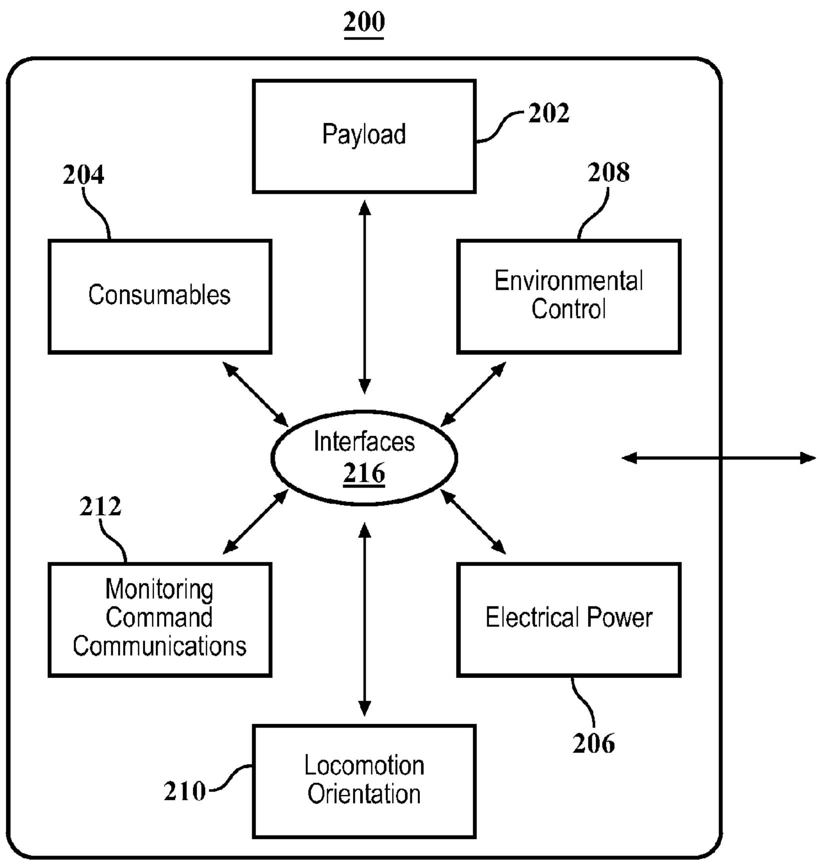
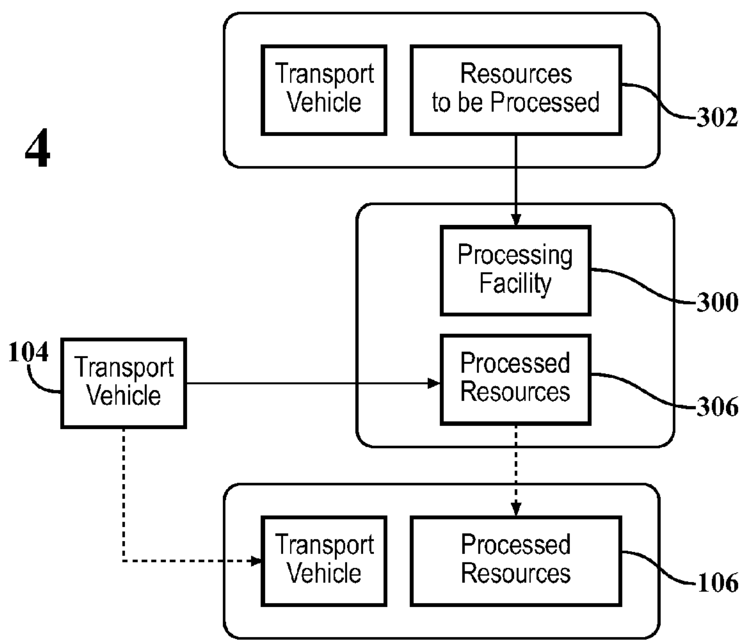

200
Payload
202
204
208
Consumables
Environmental Control
Interfaces 216
212
Monitoring Command Communications
Electrical Power
206
210
Locomotion Orientation

FIG. 4


Transport Vehicle
Resources to be Processed
302
Processing Facility
300
104
Transport Vehicle
Processed Resources
306
Transport Vehicle
Processed Resources
106

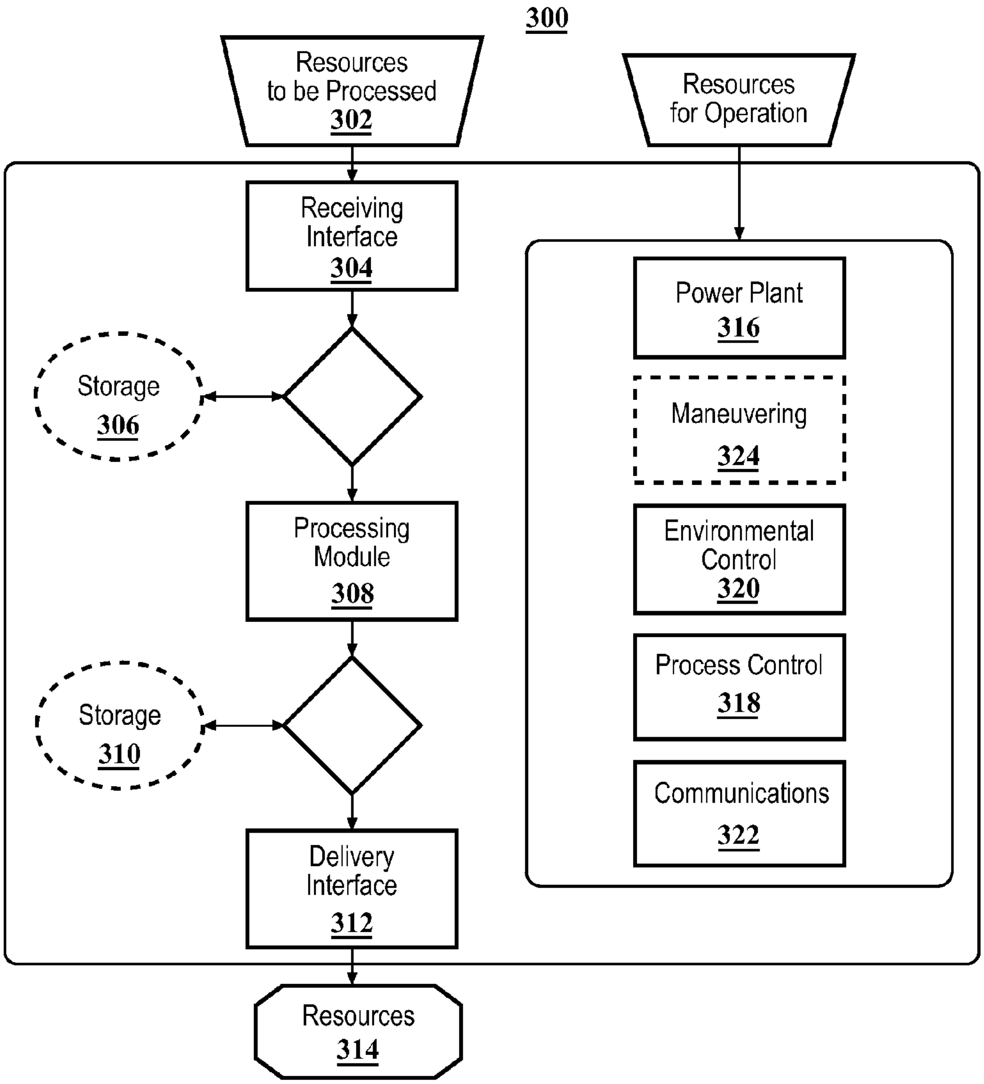

300
Resources
to be Processed
302
Resources
for Operation
Receiving
Interface
304
Storage
306
Processing
Module
308
Storage
310
Delivery
Interface
312
Resources
314
Power Plant
316
Maneuvering
324
Environmental
Control
320
Process Control
318
Communications
322

FIG. 3

FIG. 5

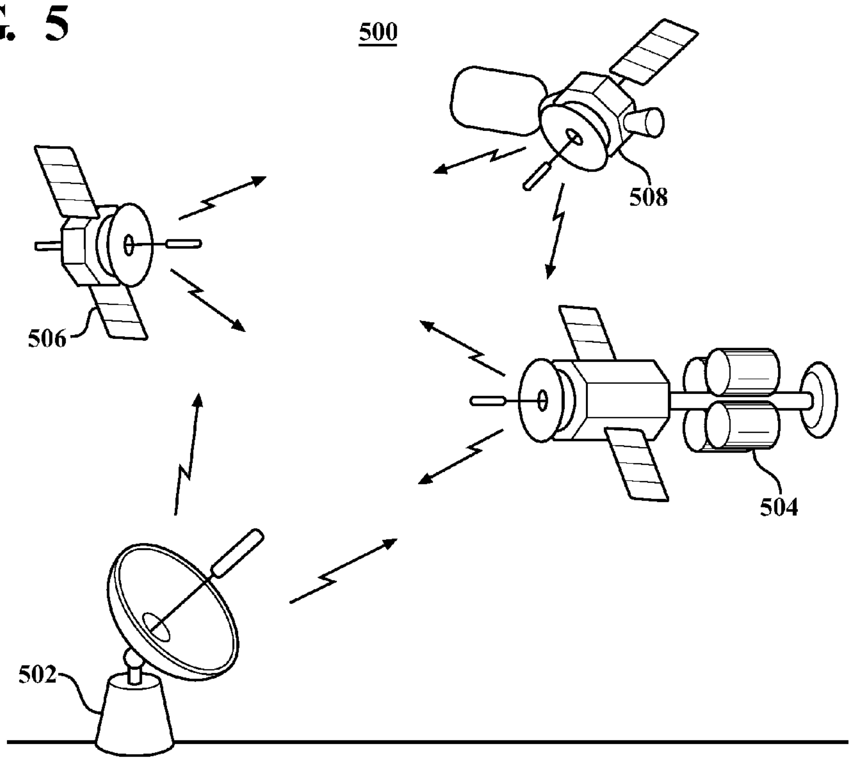

500
508
506
504
502

FIG. 5A

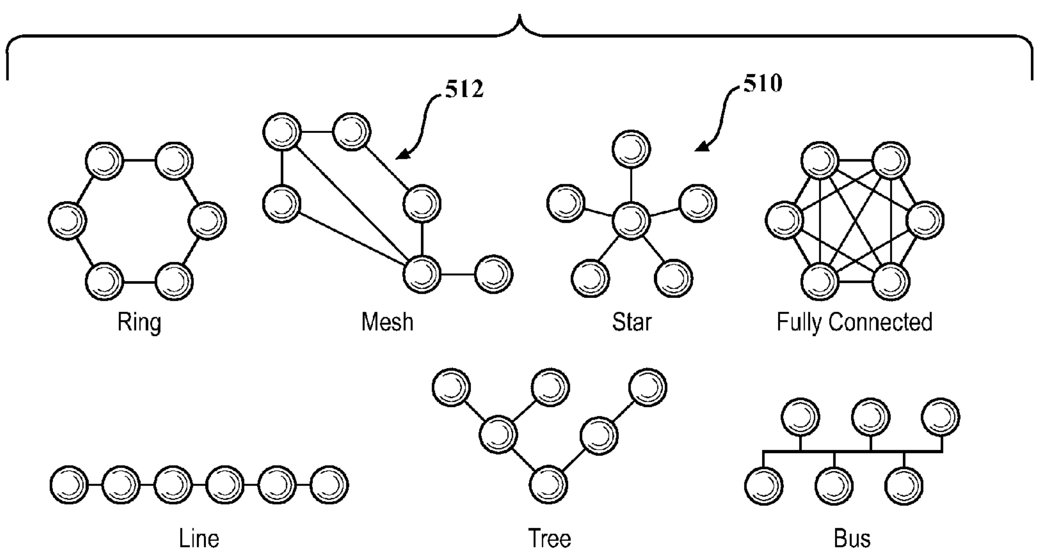

512
510
Ring
Mesh
Star
Fully Connected
Line
Tree
Bus

FIG. 6

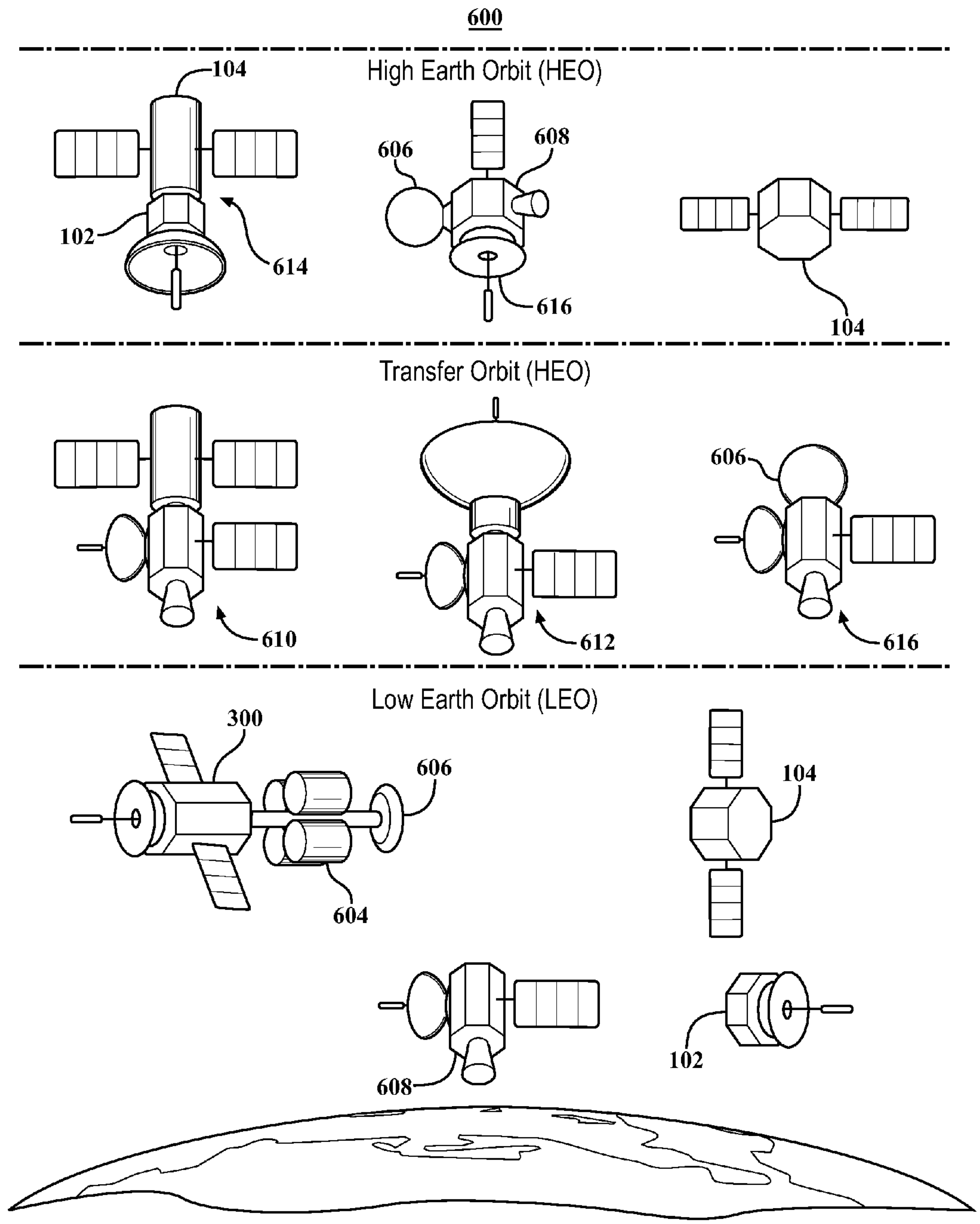

600
High Earth Orbit (HEO)
104
606
608
102
614
616
104
Transfer Orbit (HEO)
606
610
612
616
Low Earth Orbit (LEO)
300
606
104
604
608
102

FIG. 7

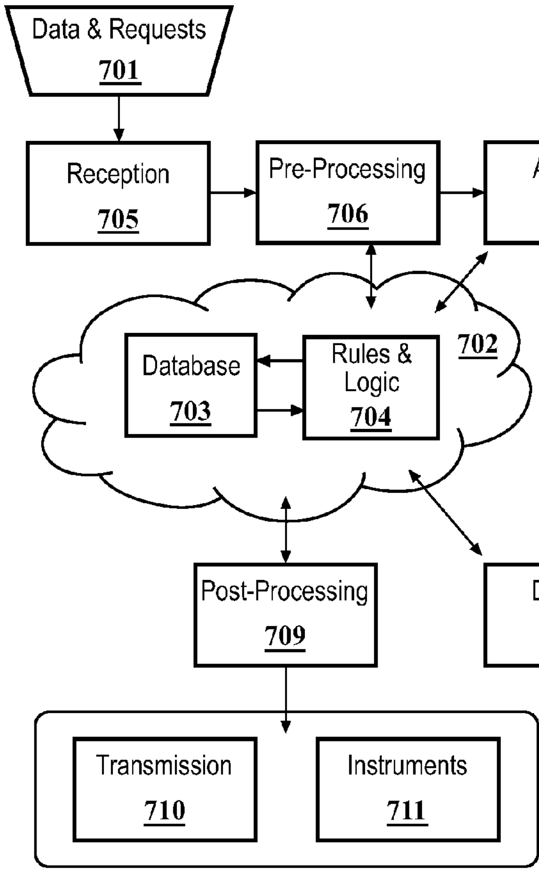
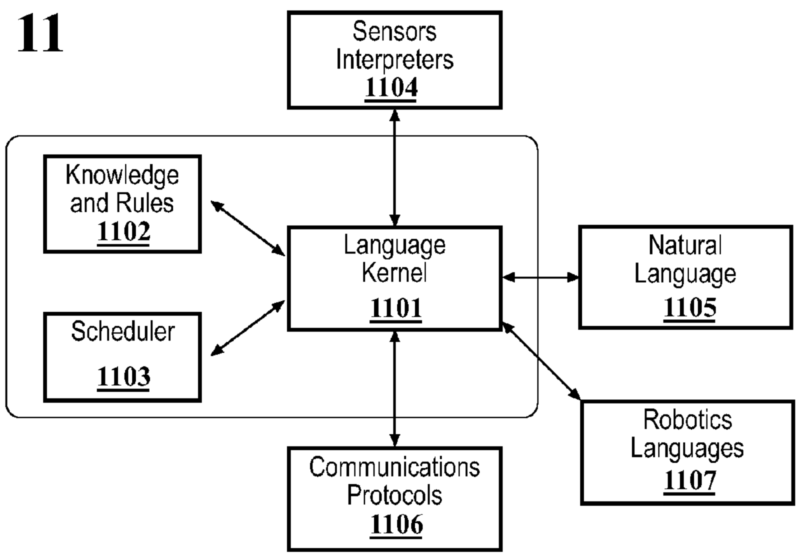

Data & Requests
701
Reception
705
Pre-Processing
706
Analysis
707
702
Database
703
Rules & Logic
704
Post-Processing
709
Decision
708
Transmission
710
Instruments
711

FIG. 11


Sensors Interpreters
1104
Knowledge and Rules
1102
Language Kernel
1101
Natural Language
1105
Scheduler
1103
Robotics Languages
1107
Communications Protocols
1106

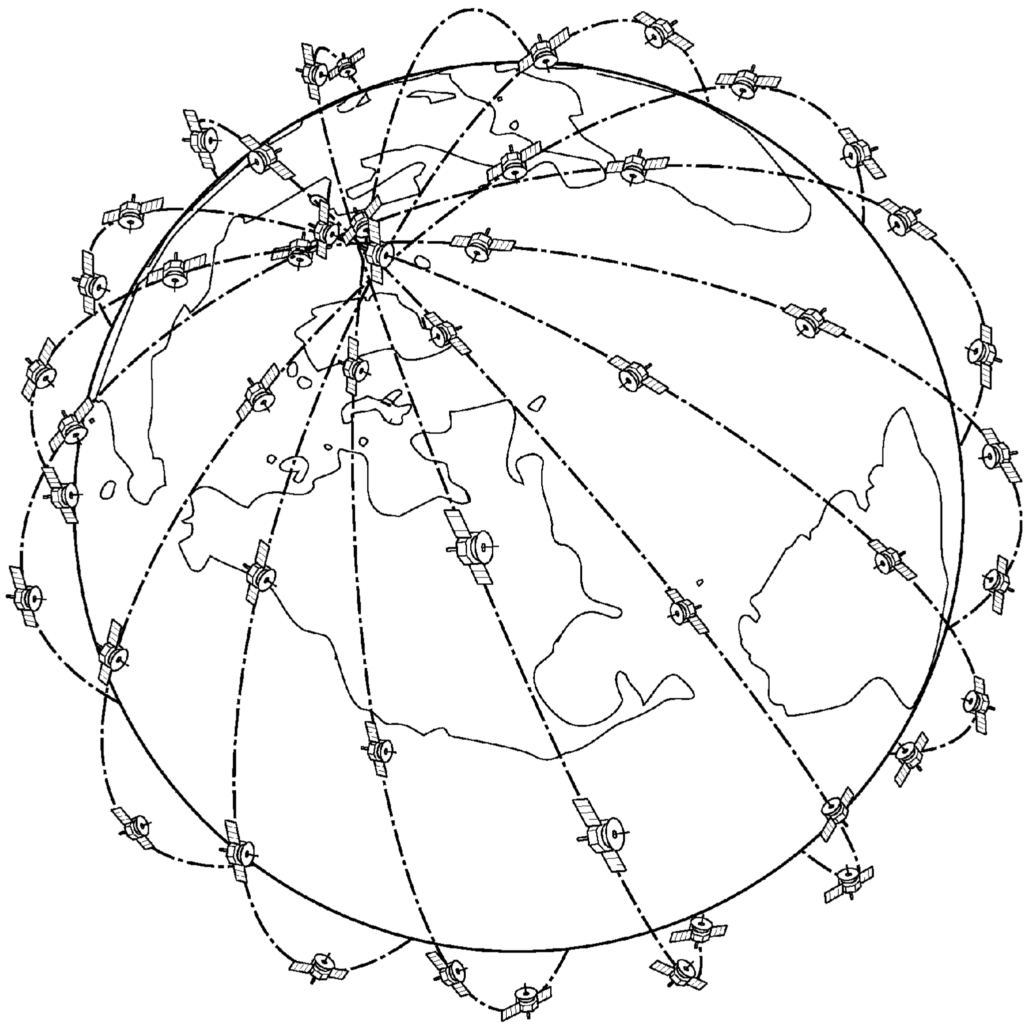


FIG. 8

FIG. 9

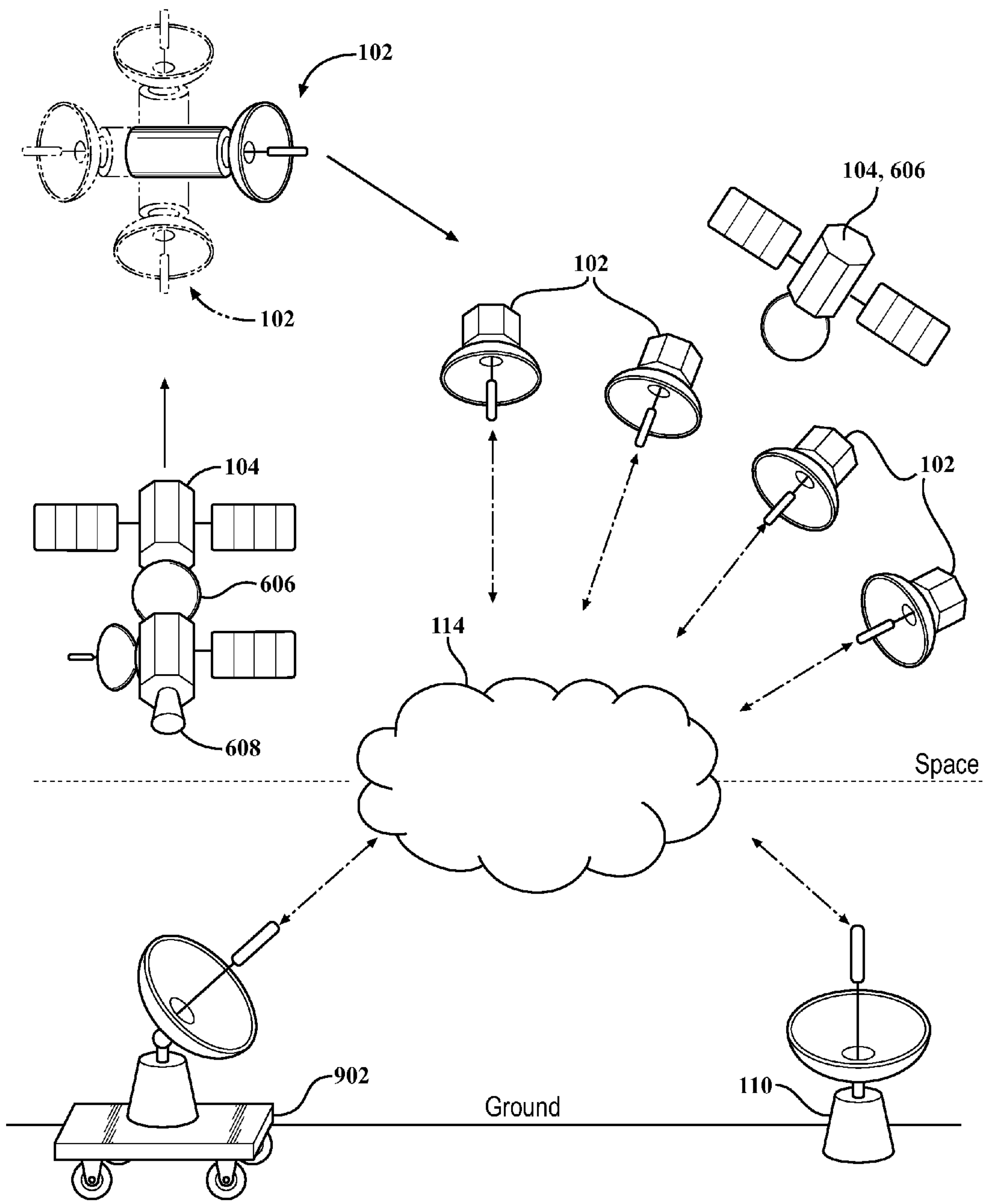
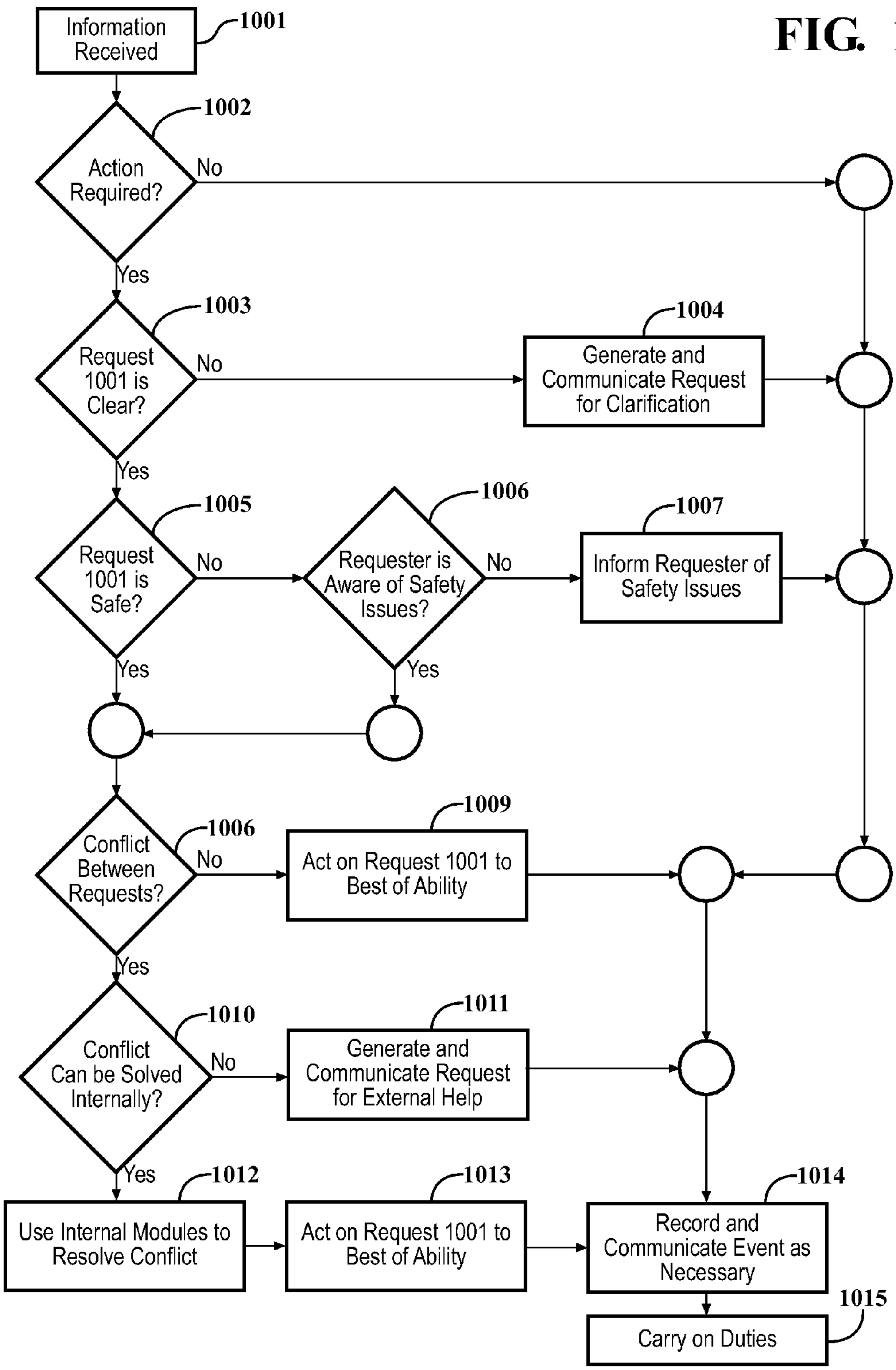

102
102
104, 606
102
104
606
608
102
114
102
Space
902
Ground
110

FIG. 10


Information Received
1001
1002
Action Required?
No
Yes
1003
Request 1001 is Clear?
No
1004
Generate and Communicate Request for Clarification
Yes
1005
Request 1001 is Safe?
No
1006
Requester is Aware of Safety Issues?
No
1007
Inform Requester of Safety Issues
Yes
Yes
1006
Conflict Between Requests?
No
1009
Act on Request 1001 to Best of Ability
Yes
1010
Conflict Can be Solved Internally?
No
1011
Generate and Communicate Request for External Help
Yes
1012
Use Internal Modules to Resolve Conflict
1013
Act on Request 1001 to Best of Ability
1014
Record and Communicate Event as Necessary
1015
Carry on Duties

UNIVERSAL SPACECRAFT ARCHITECTURE

RELATED APPLICATION

[0001] This application claims priority to and the benefit of the filing date of provisional application, U.S. Ser. No. 61/777,215, filed on Mar. 12, 2013.

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TECHNICAL FIELD

[0003] The technical field is the system, method and apparatus for launching spacecraft and spacecraft modules into orbit and configuring the orbiting modules as needed into various vehicle configurations. The modules have multiple capabilities necessary for a spacecraft. These are, among others, payload, propulsion, fuel, refinery, resource processing, communications and schema management and optimization.

BACKGROUND

[0004] Monolithic rockets launch payloads into orbit carrying all of the functions for the mission. The monolithic vehicle has launch and maintenance costs associated with a combined vehicle and payload. Payloads in orbit have a limited useful life and expire. The launch components either reenter the atmosphere and burn or orbit as space junk. There is a need for a more efficient spacecraft system to reduce costs with reusable components. Likewise there is a need to have fuel available in orbit to refuel spacecraft modules. Propellant refined in orbit and supplied to modules as needed lowers costs and increases the flexibility of payloads. Likewise, there is a need to provide communications to connect the space vehicles and components to allow the management of a flexible space vehicle schema. And an optimization schema is needed to manage components and assembly of components into space vehicles and the resources for the components and vehicles.

[0005] Additional aspects and advantages of this device will be apparent from the following detailed description of examples, which proceeds with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** is a schematic of a modular spacecraft system.

[0007] FIG. **2** is a representation of a spacecraft assembled from modules.

[0008] FIG. **3** is a diagram of a resource processing facility.

[0009] FIG. **4** is a diagram of a schema for processing and transport of resources.

[0010] FIG. **5** is a representative communication network for the modules.

[0011] FIG. **5**A is a representation of alternative communications network configurations.

[0012] FIG. **6** is a module assembly schema.

[0013] FIG. **7** is a schema for processing information received by an agent for space module communication, optimization and control.

[0014] FIG. **8** is representation of the components and trajectories of a star-type communications satellite constellation in low earth orbit.

[0015] FIG. **9** is a representation of a ground and space communications network for a scientific mission and the organization of space components from stand-by to active configuration.

[0016] FIG. **10** is a diagram of the logic for processing data and requests received by a space module.

[0017] FIG. **11** is a schematic representation of a communication and functional language for managing modules in orbit.

DETAILED DESCRIPTION

[0018] The term space as used in this specification means the region lying beyond an altitude of 100 km above the Earth's mean sea level (MSL). The terms spacecraft, satellite and space vehicle may be used interchangeably and generally refer to any orbiting satellite, interplanetary vehicle or spacecraft system. The term element and module may be used interchangeably and generally refers to components of a spacecraft, satellite or space vehicle. When an element is referred to as being connected, mated or coupled to another element, it can be directly connected or coupled to another element, or intervening elements may be present. Furthermore, connected, mated or coupled may include wirelessly connected, mated or coupled. Likewise the term first and second used to describe various elements does not limit the elements. It is a way to distinguish one from another.

[0019] A space schema based on modules allows assembly and reassembly of spacecraft components in space into vehicles. The vehicles provide transportation, consumables, power and propulsion for payloads in support of automated and manned space missions. The vehicles are assembled from modules serving specific functions. For illustration, some of the functions are propellant storage, energy storage, orbit transfer, station keeping, communications, command and control, habitat, and additional functions as needed. The vehicle consists of several modules that each accomplishes specialized tasks.

[0020] A payload module contains the resources to be transported by the vehicle. Example are raw materials as inputs for the resource processing facility, refined materials produced by the facility, manufactured hardware, scientific instruments, power plants, habitats, entire vehicles or entire facilities.

[0021] A consumables module contains propellants or energy sources such as hydrogen and oxygen, raw materials, or nutrients for living beings.

[0022] An electrical power module typically has solar arrays, batteries and a power-processing unit for providing electricity to the other modules. The function of this unit includes power regulation, power routing and switching, voltage regulation, and AC/DC conversion and like electrical systems management functions.

[0023] An environmental control module monitors and regulates the vital parameters of the modules within the vehicles, such as temperature, pressure, atmosphere and radiation.

[0024] A locomotion and orientation module typically consists of a set of rocket thrusters and their associated propellant tanks and regulation systems for moving the entire vehicle between locations, and for station keeping, drift correction, and rotating the vehicle to a specified direction.

[0025] A monitoring, command and communications module manages the flow of information and commands within the vehicle, and between the vehicle and the outside.

[0026] The modules are connected through various types of interfaces. Compatible mechanical, communications, and command interfaces allow interchangeability. Interface examples are, mechanical joints, mating mechanisms, consumable transfer valves, electrical connectors and data transfer connector. The vehicle also has various types of interfaces for connection and transfer of resources and data with resources processing facilities and other vehicles. Docking mechanisms, flow pipes and valves facilitate resource transfer. Communications interfaces may be either physical or transmissions in all wavelengths based on data formats, protocols including analog signals. All radiation spectrums may be used for communications.

[0027] Modules and elements have different functions and life spans. For example, structural elements have low wear rates and can be used for decades, if not longer. Modules and replaceable elements allow for replacement of old technology and failed components. Uniform interfaces facilitate upgrades and replacement of elements and modules.

[0028] A space schema described in this document has a resource processing facility and one or more vehicles, all primarily operating out of the Earth's atmosphere, that is, on or near a celestial body a planet, an asteroid, or other type of celestial body, in near Earth orbit, or in deep space.

[0029] As previously described, The vehicles provide transportation, consumables, electric power, propulsion, and other services to payloads in support of a variety of space missions, automated or manned. The vehicles may also transport resources to the facilities and may deliver processed resources to other vehicles. In general, the vehicles comprise several modules each serving a specific function that can be assembled into a single vehicle. An assembled vehicle may include any of these specific functions; propellant storage, energy storage, orbit transfer, station keeping, communications, command and control, habitat and other functions.

[0030] A refinery processes resources collected on site or from other locations for use as propellant, energy carriers, structural components, manufactured hardware, life support consumables, and other uses. Facilities may have power plants, resources processing devices, environmental control and process control modules, receiving and delivery interfaces, and may be monitored and controlled on site or remotely. The facilities may be manned or unmanned. Variations of the facilities also have storage modules for resources and end products, and have maneuvering modules for controlling or changing the location of the entire facility. The facilities may come in various configurations: refinery, recycling center, factory, farm, or other configurations.

[0031] Components can be engineered for the space environment as required. An example is that all components need not be hardened for radiation. Environmental conditioning is dependent on a module's system requirements and may vary among modules.

[0032] Launching modules instead of an entire vehicle allows the use of various launch vehicles with load specific risk considerations. For example, low value payload merits lower reliability launch vehicle and protocol and less expense. For example, propellant or materials for manufacturing may be launched separately thereby minimizing risk to an expensive payload.

[0033] Shown in FIG. **1**, is a schema **100** for a spacecraft assembled from orbiting modules and moving modules and spacecraft in orbit and between orbits and interplanetary trajectories. A payload **102** is launched into orbit, typically a low earth orbit (LEO). The payload may be any one of multiple packages such as experiments, surveillance equipment, fuel, raw materials, life support resources, humans, etc. Once in LEO a service vehicle module **104** provides transportation, consumables, electric power, propulsion and other services to payloads in support of a variety of space missions. Service vehicle module **104** mates with the payload module **102** to transport it to another orbit or position the payload module **102** within an orbit. The service vehicle module **104** may provide supplies to the payload module **102** as needed. The service vehicle module **104** moves and mates modules in and between orbits. The combined service vehicle **104** and payload **102** modules are propelled into High Earth Orbit (HEO). Examples of a HEO include a geosynchronous orbit, or a highly elliptic orbit such as the Molniya orbit. Modules **102** and **104** rendezvous with a propulsion service module **106** in HEO. The three-mated modules, **102**, **104** and **106** function as a spacecraft. A refinery module **108** is in LEO and accepts raw materials for processing into fuel and other materials to replenish the various modules.

[0034] A space schema **100** includes one or more vehicles and resource processing facilities. The vehicles comprise at least one service vehicle module **104** and one payload module **102**, which may be mated using a standard interface and may be separated during the mission. The payload module **102** contains the resources to be moved by the service vehicle module **104**. For example, the payload module **102** may consist of scientific instruments, telecommunication antennas and transponders, consumables storage such as fuel tanks, human habitats, or combinations thereof. The service vehicle module **104** can consist of a locomotion subsystem for example, a set of rocket thrusters with the associated electric power, propellant storage, delivery and regulation equipment. If demanded, a second service vehicle module **104** can mate the propulsion service module **106** to the payload module **102** to provide locomotion. This second service vehicle module **104** can also serve to fuel or refuel the mated spacecraft with propellant that it obtains by accessing a resources processing facility **108**. In the resources processing facility **108**, raw materials are received at an interface such as a fluid fill/drain valve and may be stored for later use. The resources processing facility **108** consists of at least one resources processing device, one resources delivery interface, one environmental control device and one process control device.

[0035] Another propellant module **106** is shown in orbit as a fuel resource. A service vehicle module **104** may mate with it and move it into LEO for refueling by the refinery module **108**. There may be multiple propellant modules **106** parked in orbit as a fuel resource. The resource processing facility **108**, referred to as a refinery **108** in this example, may turn raw materials into refined materials for other uses. For example, water collected on Earth or from other sources in space, e.g. from a comet, may be stored in liquid form and delivered to the refinery **108** via the service vehicles **104**. The water may be transferred to the storage tanks of the refinery **108** using a system of pipes and flow regulators pressured by water vapor.

The refinery **108** may be electrically powered by a system of solar arrays, energy storage, e.g., batteries and power regulation units. The liquid water available in the refinery **108** may be dissociated into gaseous oxygen (O2) and gaseous hydrogen (H2) using electrolysis. The gas products may be stored, for example, in either gaseous or liquid phase in high-pressure tanks for later use.

[0036] In a resource processing facility **300** later shown in FIG. **3**, referred to as a factory, raw materials may be turned into manufactured hardware or food and other consumables such as liquid nutrients or oxygen for living beings. A recycling center converts manufactured hardware, typically at the end of its' life cycle into energy and manufactured items.

[0037] Still referring to FIG. **1**, an Earth communication system **110** is in communication with an orbiting spacecraft **112** that has the capability to route communications among modules and vehicles. A communications schema is represented by a cloud concept **114** that uses communications elements in modules and vehicles to form a communications network. The communications cloud **114** is capable of communicating with all components in the communications schema.

[0038] Referring to FIG. **2**, a representative vehicle **200** is comprised of modules that accomplish specialized tasks. A payload module **202** contains the resources to be transported by the vehicle **200**. The resources may be raw materials to be used as inputs for the resource processing facility, refined materials produced by the facility, manufactured hardware, scientific instruments, power plants, habitats, entire vehicles or entire facilities. The consumables module **204** may contain propellants or energy sources such as hydrogen and oxygen, or nutrients for living beings. The electrical power module **206** comprises solar arrays, batteries and a power-processing unit for providing electricity to the other modules. The environmental control module **208** monitors and regulates the vital parameters of the modules within the vehicles, such as temperature, pressure. The locomotion and orientation module **210** contains a set of rocket thrusters and their associated propellant tanks and regulation systems, for moving the entire vehicle **200** between locations, for station keeping (drift correction), and for rotating the vehicle to a specified direction. The monitoring, command and communications module **212** manages the flow of information and commands within the vehicle, and between the vehicle and the outside. The modules are connected and mated through various types of interfaces **216**. There are interfaces **216** for mechanical joints, mating interfaces, flow pipes and valves for transferring consumables, electrical connectors and data transfer. The vehicle **200** also has various types of interfaces for connection and transfer of resources and data with resources processing facilities and other vehicles. For examples, docking mechanisms, flow pipes and valves, or transmission/reception antennas.

[0039] Referring to FIG. **3**, the resources processing facility **300** consists of several modules that can each accomplish specialized tasks. Liquid water is a resource **302** to be processed. It is transferred through a fill/drain valve receiving interface **304** to the storage tanks **306** of the refinery via a system of pipes and flow regulators and pressured by a system of pumps. The liquid water available in the refinery is dissociated into gaseous oxygen (O2) and gaseous hydrogen (H2) using electrolysis in a processing module **308**. The gas products are stored in high-pressure tanks **310** for later transfer through a delivery interface **312** that may be a fill/drain valve using pipes, flow regulators and pressurization devices.

[0040] Electricity for the electrolysis comes from a power plant **316** consisting of solar arrays, batteries and power regulation units. Electricity also powers other units within the refinery **108**. A process control unit **318** can start or stop the electrolysis, regulate the reaction rate, water input flow and gas output flow. An environmental control unit **320** regulates the temperature of the facility components. A communications unit **322** sends the refinery's parameters such as water and gases quantities, electric power consumption, line pressures, temperatures to a remote station or receives commands for the refinery **108**. A maneuvering module **324** consisting of rocket thrusters and their associated propellant tanks and regulation systems are attached to the refinery **108** for station keeping.

[0041] In the processing facility **300**, resources **314** are processed from raw materials or manufactured items that are susceptible to recovery procedures. Metal is one such material as is fluid and carbon based biologic materials.

[0042] Referring to FIG. **4**, a resource module **302** is sent and mated to a service vehicle module **104** as described previously. The resources can be produced on Earth, or extracted from a space body, e.g. an asteroid, Earth's moon or a comet, and sent to the service vehicle module **104** with a rocket launch vehicle. The service vehicle module **104** and the resources module **302** are mated and the entire assembly goes to the location of a resource processing facility **300** such as described previously, for example, a water electrolysis plant in LEO. The resources are transferred to the processing facility **300**, transformed into processed resources **306** such as gaseous hydrogen and oxygen and stored in a processed resources module **106**. The processed resources module **106** is mated to another service vehicle module **104** for transport to another location for refueling another vehicle.

[0043] Referring to FIG. **5**, shown is an exemplary communications schema **500** with a ground base communication facility **502**, a resource processing facility **504**, a space communications facility **506** and a resource transport vehicle **508**. Each have communication elements capable of sending, receiving, and relaying information with other components of the infrastructure using electromagnetic transmission, radio frequencies (RF), laser beam transmission or any communication signal. The information transmitted via the communications elements can include data relative to the internal status of the spacecraft. Example of data are; propellant remaining on-board, spacecraft environment data, temperature, situational data, orbital elements of the spacecraft, messages for human beings, voice and picture messages, sequences of commands for remote control, software updates and other type of information. The communications can be routine or one time, scheduled or unscheduled. The information can come from elements within a space vehicle such as an optimization element, a space-based resource processing facility or from a ground based communication facility. Communications within the network can be relayed by space based communication facilities **112** and **506** or ground facilities **110** and **502**. The communications network **114** can be organized around a central hub referred to as a star topology **510** as shown in FIG. **5**A, or distributed between the infrastructure components in various configurations such as a mesh topology **512**.

[0044] Still referring to FIG. **5**, the communications elements comprise an input and output transmission subsystem, for example, an RF antenna or a laser diode, a signal processing subsystem for performing functions such as noise filtering, signal amplification, multiplexing, DE multiplexing and other functions, and support subsystems such as power supplies, thermal control, monitoring, and other support subsystems.

[0045] Referring to FIG. **6**, a space schema **600** in Earth orbit provides telecommunications and remote sensing services to ground and space stations. The elements of the space schema are launched from the ground to a LEO at an altitude of a few hundred kilometers. A resource processing facility **300** that in some instance is a fuel refinery **108** carries containers **604** that store unrefined resources. Water is one of the preferred resources to be stored in containers **604** because of its low launch costs and risks, and its many applications, such as propellant, energy carrier or as a basic supply for manned missions. Water mined from Earth's moon or other terrestrial bodies may be resources used in the refinery. The processed resources such as gaseous hydrogen and oxygen are stored in fuel containers **606** that can stay attached/mated to the processing facility **300** or be detached/unmated for transport to another location. An orbit transfer module **608** can be mated to other modules of the infrastructure for transporting them to another orbit. The orbit transfer module **608** can use high thrust rockets such as chemical rockets for rapid transfers, or high specific impulse rockets such as electromagnetic rockets for mass efficient transfers.

[0046] In one vehicle assembly configuration **610**, an orbit transfer module **608** is mated to a service module **104**. After transfer to the geostationary orbit, the service vehicle module **104** and the orbit transfer module **608** are unmated. The orbit transfer module **608** is moved back to LEO and the service vehicle module **104** remains in HEO using high specific impulse rockets.

[0047] In another vehicle assembly configuration **612** an orbit transfer module **608** is mated to a payload module **102** that may consist of telecommunications antennas, transponders and support equipment. After transfer to HEO, the orbit transfer **608** and the payload **102** modules are unmated. The payload module **102** is mated to a service vehicle module **104**. In this satellite assembly configuration **614**, the service vehicle module **104** provides electric power to the payload module **102** and uses high specific impulse (i.e. mass efficient) rockets for keeping the entire assembly **614** on station.

[0048] In another vehicle assembly configuration **616** an orbit transfer module **608** is mated to a processed propellant container **606**. Once in HEO, the vehicle assembly **616** ferries the propellant container **606** between HEO slots for refueling service vehicle modules **104** that are standing alone or are part of a satellite assembly **614**. Once the processed propellant container **606** is depleted, the entire assembly **616** is moved back to LEO, the container **606** and the orbit transfer vehicle **608** are unmated, and the container **606** is mated to the resource processing facility **300** for replenishing.

[0049] In another vehicle assembly configuration, an orbit transfer module **608** is mated to a combination of service vehicle modules **104**, payload modules **102** and processed propellant containers **606** for transfer to HEO.

[0050] The orbit transfer module **608** can accomplish other missions such as the relocation of satellite assemblies in HEO to other orbital slots or move inoperative or obsolete modules/assemblies to a repair/disposal space-based facility not shown.

[0051] The space infrastructure described in previous sections is managed by a dedicated management system. The function of the system is to optimize the use of the various modules of the infrastructure for fulfilling its mission and for best performance. For example, in a telecommunication constellation **114**, the system can monitor the flow of data through the constellation and respond to an increased flow to or from a ground area, e.g. a city by allocating more transponder capacity to that area. The constellation's structure **114** is flexible as described in previous sections, e.g. the orbital elements altitudes, inclination angles, etc. and the various hardware modules of the constellation can be reorganized to satisfy the operator's needs. In order to respond to changes in data flow, the constellation management system can then use various optimization tools to choose between many options: modify transponder allocation times, move communications payloads to different orbits, etc. Example optimization tools are: evolutionary strategies, genetic algorithms, Monte Carlo simulation approach, and multi-state/multi-objective strategies. The constellation management system comprises data and logic that can be stored in various pieces of hardware such as hard drives or flash memories in one or more modules and can be modified by command or automatically by another software system.

[0052] An agent is defined as a spacecraft module, or a set of spacecraft modules, that is capable of receiving external or internal information, processing it and acting upon it. Information may be broadly classified as data and requests. When a data is received, the agent can be either passive or active, whereas when a request is received, the agent is expected to act upon it if possible and according to the rules of operation for this agent.

[0053] Shown in FIG. **7**, is a schema for processing information **701** received by an agent for space module communication, optimization and control. During the process, the agent may interact with the management system **702**, which may be stored entirely within the agent, entirely outside the agent or partly inside and partly outside. The management system is composed of a database module **703** that receives, stores and delivers information, e.g. measurements from sensors, user-defined mission rules, orbital parameters and rules and logic module **704**, that can help in evaluating and optimizing the various options for responding to requests. The interaction between the agent and the database **703** may be receptive or active. In a receptive mode the agent retrieves information from the database. In the active mode the agent modifies the database. Both receptive and active modes may operate concurrently.

[0054] A reception module **705** that may be an optical, radar, thermal or mechanical sensor, or a communication antenna first receives the information **701**. The output signal from the reception module **705**, for example, a time-varying voltage then goes to a pre-processing module **706** and is converted into a format that can be analyzed by the agent in module **707**. Examples of pre-processing modules **706** are an analog to digital converter, image recognition software, or speech recognition software. An analysis module **707** then translate the information into a result that is meaningful to the agent in relation to its status, its mission or both, including options on how to react to the information **701**. For example, if the agent is a constellations of telecommunication modules that receives a request for more data bandwidth around a specific ground region, the analysis module can evaluate the requirement and determine if the infrastructure has the capability to fulfill the request, and if the answer is yes, the various options for responding to the request such as moving module transponders to different orbits, assigning more power and propulsion modules in support to a module antenna cluster, etc. are considered.

[0055] The results from the analysis module **707** are sent to the Decision module **708** and it decides on the best course of actions for the agent. The decision generated by module **708** is sent to a post-processing module **709** for conversion into a format understandable by the agent's output module. Examples of post-processing modules **709** are a language compiler for a mechanical controller or a speech synthesis module. Output modules may be information transmission modules **710**; or an RF antenna, instrument module **711**, a robotic arm or a propulsion module. In the above example of a communication constellation, module **708** may decide (i) to use a propulsion module to move several payload modules including transponders and antennas to new orbits that will optimize the coverage area over the region specified by the operator, and (ii) to assign or reassign and organize the communication links between the payload modules, the various relays in space and on the ground and the operator.

[0056] A description of this exemplary process including examples is given below in table 1.

[0057] The system architecture described above can be used as an elementary building block of the global management system of the space infrastructure. Agents can be organized in groups that are characterized by functions, resources, and like capabilities. Each group can have its own meta-agent architecture. For example, one agent can be entirely hosted by a module, with a payload consisting of a transponder and an antenna for relaying communication of data and systems for managing the internal electronics of the module. Compatible modules may be grouped in a cluster orbiting in close formation. To optimize the assembly, a cluster management logic hosted by the management system **702** configures the cluster's module elements, orientation, transmission power and other operational parameters and composition for the selected mission. The resulting configuration may have multiple capabilities and roles. For example it may process signals among modules in accordance with rules in the logic to achieve best performance. In this capacity it may act as a phase array antenna. Or it may be configured to act as a virtual aperture.

[0058] The following describes exemplary space architecture and how the management system is used to optimize performance. Modules, such as described in previous sections including without limitation payloads, propulsion modules, resource processing stations, orbit transfer modules, etc. are organized in a star-type satellite constellation in Low Earth Orbit (LEO) as schematically represented in FIG. **8**. The constellation is used for remote sensing and telecommunications. At various positions within the constellation, groups of modules are stored and ready for use. Each module carries a specialized type of payload, for example, a sensor for ground observation comprised of visible, IR, radar or a communication transponder for relaying transmission of information. When not in use, the modules are gathered and packed in storage orbits, for example as shown in FIG. **8**.

[0059] An example of a mission specific module configuration and use is a scientific mission in the Arctic region collecting and analyzing data on the climate and the fauna. The mission is conducted in coordination with other scientific projects around the globe and requires real-time, high-speed data transmission. Moreover, the scientists in the Arctic are required to changed location often. The mission management team can rent telecommunications capacity from the constellation's operator. On request, selected module groups are unpacked from orbital storage and moved to operational orbits where they are deployed in synthetic aperture cluster configurations. Observation modules and scientists on the ground collect data that is transmitted via the transponder modules.

[0060] The constellation management system evaluates and optimizes in real-time the best configurations for the modules clusters including orbital elements, orientation of the synthetic aperture and the best use of the space infrastructure's resources such as number of modules to be used, type of payload, data transmission power, refueling strategies and like characteristics and capabilities.

[0061] For example, other missions that may take advantage of the optimized performance of the space infrastructure include information transmission in disaster area, where other communication infrastructures are inoperative or absent, or high-quality, low-cost in-flight entertainment and communication in passenger airplanes.

[0062] FIG. **9** is a schematic of the earth and orbit communication network using cloud **114** communications to process payload modules **102** command and control signals. Modules **102** may be stored in orbit and commanded to perform a function in response to signals from an Earth communication system **110** or a mobile Earth communications system **902**. Communication may be both ways between and among the various modules and communications systems. Also shown for illustrative purposes is a configured service vehicle module **104** mated to a fuel container **606** standing to move fuel to modules as commanded. Another exemplary module configuration is the orbit transfer module **608** mated with a service vehicle module **104** and fuel module **606** to acquire one or more payloads **102** to move into orbit or mate with other modules as commanded by grounds stations **110** and **902**.

[0063] Referring to FIG. **10** is an exemplary diagram of the logic for a fuel processing station in low Earth orbit senses an approaching vehicle. FIG. **10** and Table 1 below describe several possible sequences of events, depending on the intentions of the approaching vehicle and other parameters. During these scenarios, the station may have to deal with issues of communications, identify the vehicle, establish two-way transmission link with the proper protocol, collision avoidance, resource management considering available fuel in the station and vehicle requirement, information security, protection of the vehicle depending on the vehicle's origin and intention, internal command and control of the station's propulsion modules, fuel processing modules and other parameters reporting to the ground control center and other issues. Most likely, the agents, operators and devices understand different languages and follow different communications protocols. For example, the operators use natural language as opposed to machine language. In another example, the sensors and instruments in the various modules of a constellation may use different processing and command and control languages.

[0064] FIG. **10** is a schema for processing information received by an agent for space module communication, optimization and control previously shown in FIG. **7** and is referenced in Table 1 below and cross-referenced to steps in FIG. **10**. A description of this exemplary process, including examples is given in Table 1 below.

TABLE 1

Steps	Elements	Examples of Rules
1001	Initial state parameters of the agent may be recorded in Database 703. Information is received by reception module 705. Information may come from within the agent and from outside the agent.	Fuel processing station in Low Earth Orbit detects approaching vehicle and incoming transmission. Station approach control subsystems are automatically switched from standby to active.
1002	Pre-processing module 706 and analysis module 707 may determine if an action is required, i.e. whether information 1001 is a data or a request.	YES: approach is not part of the station schedule. NO: approach and transmission are part of a scheduled refueling maneuver and all parameters are nominal.
1003	Pre-processing module 706 and analysis module 707 may determine if the request 1001 is clear.	YES: transmission contains request for docking following standard procedures. NO: transmission does not contain a statement of intention nor reason for its' unscheduled approach.
1004	Decision module 708 may generate an appropriate request for clarifying information 1001. Request for clarification is sent through post-processing module 709 and transmission module 710.	Station sends to vehicle request for statement of intentions.
1005	The meaning of "safe" may be recorded in database 703 and determined by pre-processing module 706 and analysis module 707.	YES: station and vehicle are not in a collision course. NO: station and vehicle are in a collision course.
1006	Pre-processing module 706 and analysis module 707 may determine if the requester is aware of the safety issues. Unclear results are treated as NO.	YES: vehicle has communicated maneuver simulations and safety procedures to station. NO: vehicle has sent only basic request for docking and no other information.
1007	Decision module 708 generates information to requester about safety issues. Information is sent through post-processing module 709 and transmission module 710. Request 1001 is put on hold until further notice.	Station communicates to vehicle analysis results that predict high probability of collision. Station requests from vehicle information regarding maneuver and safety procedures.
1008	Analysis module 707 determines if request 1001 is in conflict with other information (external or internal to the agent).	YES: all docking ports on station are already taken. NO: docking ports available on station.
1009	Request 1001 is accepted. Decision module 708 determines the best course of actions and may send commands and information to post-processing module 709.	Station sends acceptance of request to vehicle and confirms approach and docking procedures.
1010	Analysis module 707 determines if agent alone can solve conflict from 1008.	YES: one of the vehicles docked at the station is departing soon and the approaching vehicle's flight plan can accommodate the wait. NO: all vehicles have high-priority missions under different chains of command.
1011	Decision module 708 generates request for outside help in solving conflict from 1008. Request is sent through post-processing module 709 and transmission module 710. Request 1001 is put on hold until further notice.	Ground command center for station is informed of docking port congestion and asked for instructions.
1012	Analysis module 707 and decision module 708 solve conflict from 1008.	Station generates simulations of holding pattern for approaching vehicle.
1013	Same as 1009.	Station informs approaching vehicle of docking port congestion and schedule. Station sends to vehicle instructions for holding pattern.
1014	Analysis module 707 and decision module 708 determine if, and what parts of, the event must be recorded to database 703 and communicated though post-processing module 709 and transmission module 710.	Station logs relative to the vehicle (identification, approach parameters, communications, etc.) are sent to ground control center.
1015	Final state parameters of the agent may be recorded in Database 703.	Station approach control subsystems are switched to standby mode.

[0065] Referring to table 1 above and FIG. **10**, the exemplary steps in data process flow information, referred to as data, is received **1001** and referred to a decision node **1002** at which point a binary decision is made. As a matter of principal, when a node is denoted as binary it is an example not a limitation. The node may have more than two decisions options such as a what-if-analysis. If the data receives a "yes" it moves to node **1003** if "no" it moves to node **1004** to request clarification. Node **1003** determines if the data is clear and if yes it continues on the yes path and moves to node **1005** that performs a safety check. At node **1005** a determination that the data has a safety issue it is referred to node **1006** where the requester originating the data is informed that there is a safety issue **1007**. If data from nodes **1005** and **1006** may have a conflict on whether the data is safe the conflict is resolved at node **1008**. An alternative decision to act on the conflicted data may occur at node **1009**. A decision on whether the conflicted data can be resolved internally is made at node **1010** and if not a message is generated requesting external help at node **1011**. A determination at node **1010** that the data can be resolved internally is made at node **1012** and the corrective action is taken at node **1013**. The approved data is moved to node **1014** and cleared for use by the system at node **1015**.

[0066] The space infrastructure system may use available programming languages and protocols to implement the various management systems and instruments such as sensors, communication instruments, mechanical or chemical hardware, etc. The Common Space Infrastructure Language (CSIL) is a framework for exchange of information using communications protocols, control and command of dynamic hardware and robotics language to provide an interface with human operators. Natural language processing may be used with the human interface. One objective of the CSIL is to give the space infrastructure the best communication tools for dealing autonomously and efficiently with a great number of agents evolving in an environment that can be highly dynamic, complex and hazardous.

[0067] Referring to FIG. **11**, in order to handle all these issues in an efficient and timely manner, the CSIL is organized around a common language core that consists of three main modules. The Language Kernel **1101** similar to a computer operating system kernel is compiled for the agent's specific hardware and contains the concepts, vocabulary, syntax, grammar and logic, of the CSIL. A Knowledge and Rules module **1102** attached to the language kernel **1101** contains an extended database for use by an agent, including without limitation identification of the various assembled modules and other useful identification parameters, mission objectives and rules, a list of tools, instruments and methods and management and control available to the agent to fulfill its mission. A Scheduler module **1103** is also attached to the Language Kernel **1101** to set up task priorities and manage interactions with other language modules in real time. Language interpreter may be interfaced with the language core in Kernel **1101** to translate the command and control languages of other agents such as external sensors **1104**, including without limitation assembly language, C++, robotics modules, JavaScript, Python, communication networks, IPv6, operators, English into the CSIL. A communications protocol **1106** recognizes the language of a signal and its destination to a module function and converts the signal into a compatible language of the receiving module. An example is robotics language **1107** that drives a physical action. A command signal may be in a different language and must be converted to be actionable by the robot. In effect the communications protocol is a schema comprising command sets that may be activated by a library of commands and converted to a library of actions. The libraries may be based on common commands, icons and language created for the actions and commands. In effect, the protocol may create its own lexicography based on language sets or from acquired knowledge. And a signal feedback loop uses the same methodology. All the modules described above may be modified to adapt to new situations or for upgrades.

[0068] It will be obvious to those having skill in the art that many changes may be made to the details of the above-described examples without departing from the underlying principles of the matter described herein. The scope of the claimed subject matter should, therefore, be determined only by the following claims.

We claim:

1. A spacecraft system comprising:

at least two orbiting modules;

module assembly rules;

module command and control systems;

command and control signals; and

applying command and control signals to a module command and control system using module assembly rules to assemble at least two modules into a vehicle.

2. The spacecraft system of claim **1** further comprising module status rules.

3. The spacecraft system of claim **1** further comprising mission requirement rules.

4. The spacecraft system of claim **1** further comprising module status and missions requirement rules.

5. The spacecraft system of claim **1** further comprising a module communication protocol.

6. The spacecraft system of claim **1** further comprising constellation management data and logic.

7. The spacecraft system of claim **1** further comprising translating module status information.

8. The spacecraft system of claim **1** further comprising cluster management logic.

9. A spacecraft assembled from selected orbiting modules comprising;

a propulsion module;

at least one fuel module;

at least one communication module;

at least one mission module;

the propulsion module configured for being removably mated to the fuel module, the communication and the mission module, the propulsion module providing propulsion for moving the fuel module, the communication module and/or the mission module if mated thereto, the propulsion module adapted to move the fuel module, the communications module or the mission module orbit to orbit, and the propulsion module moving the fuel module, the communication module and the mission module into a removeably mated configuration to form the spacecraft.

10. The spacecraft of claim **9** further comprising a logic.

11. The spacecraft of claim **9** further comprising mission requirement logic.

12. The spacecraft of claim **9** further comprising status and missions requirement logic.

13. The spacecraft of claim **9** further comprising a communication protocol.

14. The spacecraft of claim **9** further comprising command and control language.

15. A spacecraft module management system comprising:

accessing orbiting module command and control systems;

adopting configuration rules for at least one module;

instructing a module to activate its' command and control system to configure the module; and

applying the rules to configure a module in response to the command and control system.

16. A communication protocol for an orbiting space module's management and control system comprising:

a lexicography of the module's data structures and system commands;

a selection of module commands to interface with external agent communications;
a communication format to convert the agent communication to the module's lexicography; and
an interpreter of agent originated communication into the module's lexicography.

17. A module communication network, comprising:
common language protocols associated with at least one module;
data storage in a first module;
data formatted in the first module into a common language;
a data transmission device in the first module;
a data reception device in a second module; and
a signal composed of formatted data in the first module sent to the data reception device in the second module.

18. A method of assembling a space vehicle from modules in orbit comprising:
creating modules with selected space vehicle capabilities;
placing one or more modules in orbit; and
assembling modules in orbit into a vehicle.

19. The method of assembling a space vehicle of claim **18** further comprising communicating mission requirements to a module constellation manager.

20. The method of assembling a space vehicle of claim **18** further comprising determining status of a module.

21. The method of assembling a space vehicle of claim **18** further comprising matching mission requirement with module status to select one or more modules for assembly into a space vehicle.

22. The method of assembling a space vehicle of claim **18** further comprising creating a lexicography of module commands.

23. A command and control communications network for processing signals for a space vehicle assembled in orbit comprising:
one or more modules each with at least one command and control signal receptor;
a lexicography of module command and control actions;
a transmitted module command and control signal received by a signal receptor; and
the signal referred to the lexicography and converted into a module command.

24. The command and control apparatus of claim **23** further comprising cloud based module signal processing.

25. The command and control apparatus of claim **23** further comprising a protocol to convert a signal into a language used by a module.

26. A spacecraft comprising:
a payload launched into a first orbit, the payload containing one or more resources;
a service vehicle module adapted to provide transportation to the payload, the service vehicle configured to removably mate with the payload and transport the payload to a second orbit;
a propulsion service module launched in the second orbit, the service vehicle and payload configured to removably mate with the propulsion service.

27. The spacecraft of claim **26**, the service vehicle adapted to provide supplies to the payload.

28. The spacecraft of claim **26**, the service vehicle adapted to provide electric power to the payload.

29. The spacecraft of claim **26**, the service vehicle adapted to provide transportation between the payload and the propulsion service module.

30. The spacecraft of claim **26**, the service vehicle adapted to provide transportation between the first and second orbits.

31. The spacecraft of claim **26**, further comprising a refinery module in the second orbit adapted to accept one or more raw materials for processing into fuel and other materials to replenish the payload, the service module or the propulsion service module; the refinery module configured to removably mate with the service module to refuel the spacecraft.

32. The spacecraft of claim **26**, further comprising a resources processing facility comprising at least one resources processing device, one resources delivery interface, one environmental control device and one process control device.

33. The spacecraft of claim **26**, the payload module comprising scientific instruments, telecommunication antennas and transponders, consumables storage, fuel tanks, human habitats, or combinations thereof.

34. The spacecraft of claim **26**, the service vehicle module adapted to detach from the payload during the mission.

35. The spacecraft of claim **26**, the service vehicle module further comprising a locomotion subsystem.

36. The spacecraft of claim **26**, further comprising a second service vehicle module configured to removably mate with the propulsion service module and the payload, the second service vehicle adapted to provide locomotion to the spacecraft.

37. The spacecraft of claim **26**, further comprising a second service vehicle module configured to removably mate with the propulsion service module and the payload, the second service vehicle adapted to provide fuel to the spacecraft.

38. A method of assembling a spacecraft in outer space comprising:
launching a payload into a first orbit, the payload containing one or more resources;
launching a service vehicle module into a first orbit, the service module adapted to provide transportation to the payload,
removably mating the service vehicle with the payload;
transporting, by the service vehicle, the payload to a second orbit;
launching a propulsion service module in the second orbit; and
removably mating the service vehicle and payload with the propulsion service to form the spacecraft.

39. A method of claim **38**, further comprising:
launching a second service vehicle module into the second orbit;
removably mating the second service vehicle module with the propulsion service module and the payload.

40. A method of claim **39**, further comprising:
providing fuel to the spacecraft, by the second service vehicle.

41. A method of claim **38**, further comprising:
providing transportation to the spacecraft, by the service vehicle, between the first and second orbits.

42. A method of claim **38**, further comprising:
launching a refinery module in the second orbit, the refinery module adapted to store raw materials, and turn raw materials into refined materials;
removably mating the service vehicle to the refinery module to refuel the spacecraft.

43. A spacecraft comprising:
an orbit transfer module;
a service module removably mated to the orbit transfer module for transporting the service module orbit to orbit;
one or more containers adapted for storing unrefined resources configured to be removably mated to the orbit transfer vehicle;
one or more fuel containers adapted for storing process resources c;
the one or more fuel containers configured for removably mating to a processing facility;
the orbit transfer vehicle configured for removably mating to the fuel containers for transferring the fuel containers to a different orbit.

44. The spacecraft of claim **43**, the orbit transfer vehicle having one or more high trust rockets for propulsion orbit to orbit.

45. The spacecraft of claim **43**, the orbit transfer vehicle having one or more high specific impulse rockets for propulsion orbit to orbit.

46. A method of transporting a payload module orbit-to-orbit comprising:
removably mating an orbit transfer vehicle to a payload module;
transporting the first payload module from a first orbit to a second orbit by the orbit transfer vehicle;
unmating the first payload module from the orbit transfer vehicle;
mating the first payload module to a first service vehicle module,
providing power, by the first service module, to the first payload module;
maintaining the orbit of the first payload module, by the first service module, by high specific impulse propulsion;
mating and transporting the first payload module and first service vehicle to the second orbit, by the orbit transfer vehicle, after power of the first service vehicle is depleted;
removably mating the first service vehicle to a resource processing center adapted to replenish the power of first service vehicle.

47. A method of claim **46** further comprising:
transporting the orbit vehicle back to the first orbit;
removably mating an orbit transfer vehicle to a second payload module in the first orbit;
transporting the second payload module from the first orbit to the second orbit by the orbit transfer vehicle;
unmating the second payload module from the orbit transfer vehicle; and
mating the second payload module to a second service vehicle module.

48. A system for processing information received by an agent spacecraft module for communication, optimization and control, comprising;
one or more agent spacecraft module adapted to receive external or internal information, process the external or internal information and act upon it;
a management system comprising a database module that receives, stores and delivers information to the agent;
the agent is adapted to communicate with the database module in a receptive mode where the agent retrieves data from the database, the agent is adapted to communicate with the database module in an active mode where the agent modifies the database, the receptive mode and the active mode are configured to operate concurrently;
a rules and logic module that assists the agent in evaluating and optimizing the various options for responding to requests received by the management system, comprising:
a reception module adapted for receiving information for the agent;
a pre-processing module adapted for receiving an output signal from the reception module, the pre-processing module adapted to convert the information into a format that can be analyzed by the agent;
an analysis module adapted to translate the information from the pre-processing module into a result that is meaningful to the agent, for the agent to react to the information;
a decision module adapted to receive results from the analysis module and decide how to act or respond to the information, generating decision results; and
a post-processing agent adapted to receive the decision results from the decision module and converts the decision results into a format understandable by an output module of the agent.

49. The system of claim **48**, further comprising:
a global management system having groups of agents, the agents organized by groups that are characterized by functions, resources, and like capabilities, each group having its own meta-agent architecture, each group configured in a cluster orbiting in close formation; and
a cluster management system adapted for managing clusters of like modules of the grouped agents, the cluster management logic hosted by the management system configures the group's module elements, orientation, transmission power and other operational parameters and composition for a selected mission to create a resulting configuration.

50. The system of claim **49**, the resulting configuration processes signals among modules in accordance with rules in the logic to act as a phase array antenna or a virtual aperture.

51. The system of claim **49**, the cluster management system comprising a constellation management system, the constellation management system evaluates and optimizes in real-time configurations for the agent clusters including orbital elements, orientation of the synthetic aperture and use of the system's resources including number of modules to be used, type of payload, data transmission power or refueling strategies.

52. The system of claim **47**, the management system receives, stores and delivers information comprising measurements from sensors, user-defined mission rules, or orbital parameters.

53. The system of claim **47**, the management system is internal to the agent.

54. The system of claim **47**, the management system is external to the agent.

55. The system of claim **47**, the reception module comprising optical, radar, thermal or mechanical sensor, or a communication antenna.

56. The system of claim **47**, the preprocessing module comprising an analog to digital converter, an image recognition software, or speech recognition software.

57. The system of claim **47**, the post-processing modules comprising a language compiler for a mechanical controller or a speech synthesis module.

58. The system of claim **47**, the output modules comprising one or more information transmission modules, an RF antenna, an instrument module, a robotic arm or a propulsion module.

59. The system of claim **47**,

the agent comprising a constellation of telecommunication modules;

the reception module receives a request for more data bandwidth around a specific ground region;

the analysis module evaluates the request and determines if the infrastructure has the capability to fulfill the request, if there is sufficient bandwidth; and

the decision module evaluates various options for responding to the request comprising moving module transponders to different orbits, or assigning more power and/or propulsion modules in support to a module antenna cluster;

the decision module decides to use a propulsion module to move several payload modules including transponders and antennas to new orbits that will optimize the coverage area over the region specified by the operator, and the decision module decides to assign or reassign and organize the communication links between the payload modules, the various relays in space and on the ground and the operator.

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