SMAP Proposal:

“Universally Adaptable” Utility Vehicle / Craft

Overview

The “Universally Adaptable” Craft (UAC) is an application of the Standardised Modular Systems Technologies (SMST) design philosophy. In technical terms, assets are configured around technologies that leverage reiterative systems using interchangeable modular components that follow a common interface. Breaking this down into more friendly terms, each project is designed from conception to realisation to be able to integrate with all other individual components and/or sets of components. The central underlying notion behind this project is the development and construction of a diverse set of modules, frames, and supporting components designed around standardised specifications and interfaces, permitting a “universal” set of elements to nevertheless be arranged into open configurations that can be optimised for specific missions. Furthermore, this standardised modular design would allow for specific items to be replaced and/or updated with minimal impact upon the operations of an active “fleet”.

For this pathfinder application, a Category 2 mission (10 to 20 year timeframe, or less) is proposed, in the Operations Demonstration Mission domain.

Function & Characteristics

UACs are intended primarily for crewed missions, with mission durations ranging from a maximum of a few hours (for smaller units) to a maximum of perhaps ten days (when properly configured with habitat modules. These units shall provide limited impact and radiation protections, as well as environmental provisions within a fully enclosed and sealed living space. They are generally not fitted with dedicated accommodations or general living provisions (hygiene, etc) for crew, although there is the possibility of allowance for “make-shift” accommodation measures (folding couches, etc), in the case of longer duration missions.

Composition

The UAC shall consist of the general components listed below. However, not all components would be required for all missions. Furthermore, each general component would have several possible specific variations, depending upon the operational regime and mission-determined specifications.

Each component itself would generally be composed of a selection of “plug-in” mission packages. These packages would likewise follow the principle SMST design philosophy, in that each should be designed around a common interface configuration.

- **Control Module**

  As the name implies, control modules are assemblies of packages that govern the operation of an asset. This would include all systems required to permit direct operation by a (human) controller; remote operation through direct tethered (wired) and/or transmitted (wireless) command signals; automation assisted direct or remote control ("fly-by-wire"); programmed automated guidance, with or without transmitted "assignment" and/or "revision" commands; and/or, full Artificial Intelligence (AI) guidance, with or without transmitted override commands. In order to perform these tasks, the control module will integrate the following plug-in packages:

  - Guidance Package

    At its simplest, the guidance package would consist of a manual control system that allows an operator to command the unit directly, either through mechanical, electrical, and/or electronic mechanisms. Alternatively, the guidance package would consist of a control relay system that receives and acts upon command signals from an operator; a programme package that stores and acts upon pre-programmed operating instructions; and/or, an AI package that acts directly as an independent operator subject to a set of dictated mission orders and parameters.

    In addition to these control functions, the guidance package will generally include systems that provide feedback to the operator, whether control is manual or remote. At the most basic, this would include status information and/or alert systems. Other information would include visual and/or other sensory environment displays, navigational orientation and plotting information, command confirmation, performance information, etc.

    Examples of such guidance packages would include the common throttle and "joystick" controls found on most aircraft, the steering wheel and dashboard displays found in most cars, or simply the handlebars and simple indicators mounted on a motorcycle.

  - Inertial Navigation Package

    An inertial navigation package would include mechanical and/or electronic gyroscopes and accelerometers to track inertial rotations and displacement. This would allow for some minimal guidance information should more reliable information become unavailable.

  - Navigational Sensor Suite Package

    The navigational sensor suite package includes any instrument necessary for determining orientation and location information, as well as relative guidance information. This information is especially necessary for conducting rendezvous manoeuvres. An example of such a package would be the star trackers found on most existing spacecraft and probes.

- Interactive Navigational Positioning Package

  Interactive navigational positioning packages are intended to complement the functions of navigational sensor suite packages and inertial navigation packages by allowing the reception of tracking information provided by an outside source. If necessary, these functions may replace on-board navigational functions, although this should be avoided, as exterior systems might lack the resolution necessary for close manoeuvres. Examples of these packages include GPS, fixed directional transmitters, radar relays, etc.

- Processing Hardware and Software Packages

  The processing packages are essentially computer systems that support and coordinate the functions of the other integrated packages and components.

In addition to these packages, the control module will also provide the basic shielding required to protect these integrated plug-in systems from nominal ballistic impact, radiation hazards, and any other hazard inherent to normal function.

- **Core Frame**

  The primary functions of the core frame are to: provide structural support for all components and assemblies; to provide standardised connections to link all components and assemblies; and, to act as a primary bus for electronics, power, and piping.

  The core frame does not include any sub-system packages, per se, as all other modular assemblies are essentially plug-in packages for the frame. However, the frame shall be designed to incorporate piping/conduit channels directly into the support structure, permitting the easy installation of bus "circuits", integrating the functions of connected modules. These channels shall be integrally constructed into the frame structure, providing strength and reinforcement, while allowing for a lighter overall structure, in the same way that reductive machining of the shells of the Saturn V stages allowed their mass to be reduced.

  In addition to the integral channels, there shall be a number of connector "hard-points", which shall accommodate all functional modular components and assemblies. These connector points will have a standardised configuration governing the placement of structural joints, piping joints, electrical and electronic bus conduit joints, etc.

- **Propulsion Modules**

As the name implies, propulsion modules are responsible for producing the thrust necessary for translational and rotational displacement. For the purposes of this project, this would include otherwise “passive” control surfaces that modify the fluid flow of a surrounding environment. This function would then include the following packages:

- Thruster Package(s)

  The thruster package provides the force necessary for motion, and would include any items required for providing, directing, and modifying that force.

- Thrust Assembly Structure

  Thrust assembly structures serve as mounts for thruster packages, and are further responsible for distributing the force of thrust through a given structure. In addition, these structures include features to protect surrounding structures from any resulting hazards, such as thermal loads, shock/vibration loads, etc. Several thruster packages might be mounted on a single thrust assembly structure. Thrust assembly structures may also include systems necessary to eject the structure for staging or abort manoeuvres, as well as those required for assisting in the recovery of the assembly.

- Control Surface Packages

  Control surface packages include simple surface structures, joint/hinge assemblies, and motive actuators. These packages might simply be appropriately placed to modify the fluid-dynamic flow of a surrounding media, such as water or air, or they may be placed in the exhaust stream of the thruster(s) used. Examples would include dive planes, ailerons, and rudders.

- Auxiliary Packages

  Auxiliary packages are systems and components that allow propulsion systems to be tapped to provide for other functions, and/or to facilitate and augment the functions of propulsion systems. An example of the former function would be an auxiliary generator that produces electrical power by tapping the exhaust flow from the thruster to power a turbine. An example of the latter would be a set of pumps and valves to regulate and augment propellant flow.

Propulsion modules will plug-in to standardised structural and functional connector points, located on the core frame. As with all such points, there will be a fixed orientation between piping joints, electrical and electronic conduit joints, etc.

Propulsion modules could be packaged as single central units, or for mounting in groups of two or four units.

- **Power Supply, Storage, and Conditioning Modules**

All active on-board systems will require power to operate. This requirement shall be addressed by the following components.

- Power Generator and/or Collector Package(s)
  Power generators and collectors provide power necessary for the operation of various systems. Generators produce the power themselves, often through the use of turbines that tap either ambient fluid flow or fluid flows generated by chemical or nuclear reactions. Collectors passively absorb ambient energy, generally converting that energy to electrical power.

- Power Capacitor/Storage Package(s)
  Most simply, power capacitor/storage packages are “batteries” that store and supply power (usually electrical charge, but this might also apply to hydraulic and/or pneumatic systems) to onboard systems. These units do not actually produce any power, but allow power to be tapped when generators and/or collectors are not in operation.

- Power Conditioning Package(s)
  Many, if not most, onboard systems require relatively precise configurations of electrical power. Power conditioning packages, then, provide for the carefully controlled supply and distribution of power (again, normally this would be electrical power, but there are other options, more mechanical in nature). Such functions might include conversion between direct and alternating current, augmenting (concentrating) or decreasing (stepping-down) current loads, augmenting or decreasing voltage, etc.

These modules will plug in to standardised connectors that will distribute electricity through wiring conduits nominally built into the structure of the frame, with minimal extra mass. Wherever possible, the modules will, themselves, fill spaces in the core frame structure, to provide additional strength reinforcement. Likewise, the distribution wiring would preferably be in the form of “printed” plates that also add to the frame strength.

- **Pressure Vessel Modules (including fuel and/or propellant)**
  Pressure vessel modules are simply containers used to store “fluids” (normal or cryogenic liquids, pressurised or ambient gases, particulate solids, etc) for later use. This might include combustive fuels (oxidants, reductants, and/or catalysts), propellants, pressurisers, pneumatic or hydraulic fluids, lubricants, water and air provisions, etc. These pressure vessel modules will plug in to standardised connectors that will distribute the contents through piping that is nominally built into the structure of the frame, with minimal extra mass.

For UACs, the assortment of these modules will include larger units with the capability of “wet-workshop” conversion to temporary habitat modules, intended for longer missions. These modules may be configured for “living” accommodations, either pre-arranged or for in-flight reconfiguration (when initially used for propellant containment); or, they may be configured to function as mission specific work modules.

- **Thermal Control Modules**

  Thermal control modules shall consist of all components and assemblies required for regulating on-board thermal conditions. This would include, for example, coolant reservoirs, flow piping, heat exchangers, and radiator arrays for a thermal rejection system. Again, this would be designed to plug-in to the core frame, or directly into a specific component requiring thermal control, via a standardised connector.

- **Frame Extension Modules**

  In some circumstances, the core frame module might not beef sufficient size to support all the component modules required for a given mission. In such cases, extension modules might be plugged-in, using existing connectors, to extend and reinforce the structural support provided by the frame. These extensions will be standardised components, and might themselves consist of spare core frame modules.

- **Standardised Structural Elements**

  Some missions might require more customised configurations than could normally be provided by standardised modules. To address this issue, there shall be a number of more basic standardised structural components. These would be provided exclusively through additive manufacturing (3-D) printers. Such component designs might include, but not necessarily be limited to:

  - Spinal Elements

    Spinal elements redesigned to support the linear stresses induced by thrust. Normally, this function is addressed by the core frame. This would be equivalent to the function of the spinal column and lower limbs of the human body

  - Framal Elements

    Framal elements are intended to support lateral loads, and distribute them through the spinal elements. This function is roughly equivalent to the ribs of the human body.

  - Stanchional Elements

    Stanchional elements are designed to distribute stresses through a larger area, thereby decreasing the loads applied to any given point.

  - Brachial Elements

Brachial elements provide structural reinforcement and rigidity. In principle, these elements, being more easily replaceable and less vital, are designed to fail before more important elements.

- Shells
  Shells constitute the “skin” of a structure, and are designed to provide a measure of protection for underlying components. They also provide containment, and/or other forms of isolation (or protection) between environments.

Normally, these functions are built directly into the previously specified modules, where over-redundant elements may be eliminated.

- **Mission Specific Modules**
  Mission specific modules are those components and assemblies that are specifically designed to perform required tasks. Such modules are too numerous to itemise; however, they might include such elements as mission-dedicated sensor arrays and suites, grappling and mooring arms, manipulator arms, tooling arms, extended range transmitters, narrow beam transmitters, scientific instruments, recording equipment, analytic instruments, mini- and micro- laboratories, etc.

Sample Configurations

The basic configuration of a “universally adaptable” craft would start with a conical control module (nominally sized for two persons, but capable of supporting up to four persons) mounted to an octagonal block-frame structure. The control module would have two docking ports, one of which would be docked to the core frame. Pressure vessel modules and other components would be attached internally for base configurations, except where exposure is necessary for function.

For space operations, or any environment where atmosphere or other material medium is not present, the propulsion package would normally include chemical thrusters, with the possibility of solar electric drives (such as VASIMR engines). As previously indicated, primary drive might be installed as a single central unit; however, manoeuvring thrusters would generally be mounted in groups of four.

For atmospheric or fluid media, electric- or combustion- drive shrouded propellers would be the preferred propulsion, with blade sizes determined by the desired (or required) performance parameters.

Sample Missions

The original pathfinder mission would include a 2 person, conical CM mounted on an octagonal open truss-block frame. Original “proof of concept” test “flights” would add systems supporting a four-unit underwater propulsion suite, as well as sonar suites and other underwater rated sensors. The CM would be fitted with life-support and pressurisation equipment, permitting “flights” of at least 4-hour duration. Mission specific modules would include, manipulator arms and multi-function tool sets, airlock/docking modules, habitation workshop/ lab modules, provisions supply modules, etc. These modules would support oceanic research, mining, transport, construction/repair, search/rescue & recovery, and “tugboat” operations.

Following these oceanic research trials, further optional module packages would be added, including a chassis and propulsion systems package supporting “all-terrain”/all-climate operations; followed by an airborne operations suite, swapping in systems supporting a four-unit ducted propeller propulsion package, and appropriate sensor suites. After extensive trials designed to prove the utility and versatility of the UVC, the CM will be certified for piloted space flight application, and outfitted for long-duration orbital space flight. OMS/RCS systems suites would be fitted, allowing for manoeuvring and orbital transitions. Aeronautic operations would of course preclude mining applications, as would orbital operations. These capacities would be replaced by recon operations, notably supporting search & rescue tasks. Orbital operations would add debris & hazard tagging and removal tasks, as well as on-orbit satellite repair and maintenance. The addition of future expansion packages is, of course, intended.

Although the SMST Utility Craft is intended to be outfitted with a CM supporting a fully self-contained environment, the pathfinder missions may replace this with a simple CM frame structure, providing minimal protection, but requiring the pilot(s) to be equipped with independent “environmental” suits with life support provisions. This minimised configuration would be referred to as an SMST Utility Vehicle.

Likewise, although both vehicle and craft configurations are generally intended to support direct human operation, the normally crewed CM could be replaced with a suitable automated CM. Alternatively, the human capable CM could have “auto-pilot” packages installed, allowing crewed or unscrewed missions with the same configuration.

Value Proposition

State Of The Art

SMST assets are founded upon the long established precedents that are the bases for such varied transportation resources as the common tandem truck, the common locomotive, the common car or pick-up truck (with the option of trailers), and the less common Sikorsky CH-54 / S-64 Tarhe “SkyCrane” helicopter. Similar precedents from other domains include the wide range of USB (especially “plug & play”) devices in the electronics domain, Dremel tool sets (especially the current “Speed Click” attachment line) in the home projects domain, click-on hose attachments in home gardening; just to name a few. Incidentally, all of these items, in addition to the inspiration that they have provided to the conceptual design, have direct applications that SMST will draw upon.

Purpose

The fundamental purpose of all SMST assets is to create a flexible infrastructure serving the development of space based communities, with numerous Earthbound applications as well. In the same way that the US Interstate Highway System, and all the lesser highways, streets, and smaller roads are integral to the functioning of the US economy (with the support of waterways, railways, and air-travel), SMST assets are intended to provide for all the necessities of the eventual interplanetary economy. Such an economy would of course include spacecraft, space stations, and surface bases; however, development of the Earth’s own oceans and currently remote sites (not to mention the scope of existing society) would equally be part of that future industry.

Outside of such well-established, mundane roles, the SMST line would equally provide infrastructural support to more specialised operations. Scientific research would of course be a principle interest, as vehicles, craft, vessels, and other assets deploy equipment and personnel to the outermost reaches; and would likewise be directly engaged in many such activities. Colonial development and support would be another major application; as would resource location, extraction, and transport.

Benefit

SMST assets provide the multi-use flexibility that is commonly found in the products we use in our daily lives. The primary benefit is an adaptable infrastructure that can be modified to accommodate the needs of a specific entity at a specific time.

The application of standardisation means that components will be intentionally designed to function with one another with maximum ease. Modularity allows for components to be arranged in a virtually unlimited number of configurations. It also allows for worn, damaged, or faulty parts to be easily replaced; as well as providing for future upgrades, without having to “through away” otherwise functional, or even “state of the art” parts. Applying this philosophy to different level of systems, rather than just to individual components, offers a degree of recursion that allows even greater diversity in expression.

Space is a difficult domain to operate in. Common expression is “every gram counts”. Whereas a “family car” approach to transport, with one vehicle enlisted to perform every necessary task, tends to waste resources by requiring that vehicle to carry all of the other components that it needs for other tasks, SMST can greatly streamline missions by only carrying the components required for any given mission. On the other side of the equation, where dedicated spacecraft will always outperform any other configuration in any given task, such spacecraft often perform poorly when faced with unanticipated tasks, or unexpected operating conditions. Furthermore, such craft are typically useless after completing their mission, absent the intervention of exceptional mission planners who think of new ways to use the available systems. Although SMST assets can not hope to compete with such a spacecraft in its intended domain, it allows the flexibility for mission planners to reconfigure and reuse old assets endlessly, saving costs on development and assembly; and further permits “last minute” changes in mission parameters.

End Users

In the same way that virtually every human in the developed world is an end-user for automobiles, SMST assets are intended to provide a broad-spectrum infrastructural service to anyone operating in space. This service would also be available for application in many domains here on Earth.

Proposal Team

At present, there is no actual team available for this project.