MIT GAMES-TO-TEACH PROJECT

Design Document for:

Hephaestus

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Design History

Version 1.00

Philip Tan, 14 December 2001. Initial pass at this document. Everything I did not manage to write up, I highlighted in red.

Version 1.01

Philip Tan, 14 January, 2002. Second pass. Added lava and more detail in the game setting. Deleted the index, which was not working well at all. Created first two new-user scenarios.

Version 1.1

Kurt, 13 February 2002.
Integrated previous game descriptions
Filled in all remaining parts, including pedagogy, content, and robot prototypes.
Table of contents still needed.

Version 1.2

Kurt Squire, 14 February, 2002. Added Table of Contents. Added Small-multiplayer version.

Version 1.22

Kurt Squire, 14 February, 2002. Added Cynthia’s comments.

Welcome to Hephaestus

Imagine thousands of player-controlled robots interacting in real time in a futuristic landscape. In front of you, you see a handful of small robots attempting to climb a hill in order to place objects at the top. In the far off distance, you see a team of robots building a bridge across a deep chasm. Somewhere else, teams of robots compete in basketball and soccer tournaments. Dozens of robots meander about the world, chatting, exploring, creating, and competing. All designed by AP level students; all done with simple desktop computers.

Welcome to Hephaestus. The Earth's days are numbered. Ecological and political disasters have rendered the earth inhospitable for human life. Now, humans are preparing to colonize Haphaestus, a lonely, heavily volcanic planet orbiting Rigel Kentaurus in the Alpha Centauri system. Everyone who could afford to go ahead for the trip to colonize Hephaestus has. Unfortunately, when players arrived at Hephaestus, they found the planet too volcanic for colonization. Lava flows need to be diverted, structures (bridges and buildings) need to be built, minerals need to be mined, and energy needs to be gathered via solar and wind collectors to prepare the planet for colonization. Now, players are circling Hephaestus in a space ship, controlling their robots via radio control.

Still, questions remain. Will players work together to prepare the planet for human colonization? Will they replay the mistakes of the past and destroy this planet much as they have the Earth? Will players work together, or work against each other preparing for new life on Hephaestus? The future of Hephaestus, and indeed the human race is in players' hands.

Hephaestus is a first-person, persistent multi-player where players interact with thousands of other robots on a planet in the Alpha Centauri System. Hephaestus is geologically much like Earth, but heavily volcanic – providing both opportunities for rewards in the form of plentiful mineral resources and risks, such as falling into the manifold lava flows. Building on the pedagogical successes of the FIRST Competition, Hephaestus allows players to learn by doing. Players face many critical decisions in the design of their robots. What sized battery should I use? What kinds of wheels? What materials should the chassis be constructed from? Players will wrestle with these design decisions as they design their robots down to the gear.

Astute players will quickly learn that no one robot can survive on Hephaestus alone. Players will need to scout Hephaestus' expansive terrain, which demands light, fast, fuel-efficient robots. Players will also need to divert lava, move soil, and crush boulders, which demands a sturdier robot with more torque. Every element of the world provides an opportunity for players to also master an elementary Physics concepts. Players learn about friction by designing robots that can traverse hilly terrain. Center of gravity becomes a useful concept for exploring the limits of robot design.

In Hephaestus, players learn physics to solve design problems that gain meaning through instantiation in an online community of players. In order to survive on Hephaestus, players must form alliances, forcing them to collaborate, critique designs, and share design knowledge. This approach to instruction -- collaborative constructionist learning communities, is an effective pedagogical model that has proven to be engaging and effective for supporting learning in other contexts.

Philosophy / Design Goals

Alliances are essential.
Every aspect of this game is designed for multi-player cooperation, whether it involves collaborating on a group construction project, forming an unbeatable raiding party, or simply waiting for the opportune time to betray the trust of other players. Physical and geographical limitations of the game environment mean that extended survival would be extremely difficult without allies.

Differentiation, customization, construction and homesteading are keys to success.
Players gain game play advantages by designing their robots differently from others and by creating structures that stake out land that they control over long periods of play. A differentiated squad of robots will have a far higher chance of success than a larger group of identical robots. Each player should be able to customize the abilities of his or her robot avatar to fit his or her play style best. Seizing and controlling large areas of land and lava must be effective strategies for ensuring extended survival on the planet.

Constant engagement from log-in to log-out.
The player must be able to control the robot as long as the player stays logged into the multi-player server, even if the batteries of the robot are dead or if the player is designing a stationary structure. Players will have the ability to chat or call for help at any time. However, the players' interactions on Hephaestus will be mediated through their robot at all times. This will deepen the relationship of the player with his or her robotic avatar and will increase the likelihood that players will spend time engineering their robots properly.

It must be fun.
Realism is secondary to entertainment value in this game, although the game must explicitly state which real physical laws are broken within the game engine. Any such aberrations in realism must occur only for the benefit of game play and entertainment value.

Common Questions

What is Hephaestus?
Hephaestus is a massively multi-player role-playing game that allows you to finely design your robotic avatar down to the gears. Hephaestus is also the name of the volcanic planet on which the game is set. Earth is dying, and thousands of Argo-class evacuation ships have left to colonize this new planet, dropping remote-controlled robots from orbit to the planet surface to prepare it for human habitation.

Why create this game?
Primarily, this game is designed as an entertaining, challenging, state-of-the-art, rich interactive experience to play. Multi-player gamers are always seeking more immersive, detailed and customizable gameplay. Thus, this game will cater to that desire by introducing real physics and robotics principles into character creation and operation. The game will reinforce important AP-level physics and engineering content by having game play that promotes such knowledge as a crucial tool for gaining an edge over one's opponents.

What is the planet Hephaestus like?
The planet Hephaestus resides in the Alpha Centauri star system, orbiting Rigel Kentaurus (Alpha 1 Cen), one of the closest stars to Earth and remarkably similar to Earth's sun. Generations of space exploration have only been able to find one planet capable of supporting life. Although Hephaestus is highly volcanic, the lava is extremely fertile after it cools and it is not difficult to divert the lava into broad fields that are suitable for cultivation or forestation. The climate of Hephaestus is similar to Earth's, and the ground is rich in mineral resources.

What is the setting of the game?
A large number of spacecraft are in orbit around Hephaestus, each carrying tens or hundreds of colonists from Earth. Each spacecraft belongs to a separate conglomerate, nation-state or wealthy Earth-based organization, holds a staff of robotics engineers and stores a limited supply of specialized colonization equipment, such as radio relays, self-deploying bridges and rudimentary remote-controlled robots. The robots, dropped from the ships to the planet surface, need to clear land and mine for resources in preparation for the eventual landing of the colonists.

Each organization is working separately and in competition with all the other spacecraft. Temporary alliances on the ground are common but are often short-lived, since the eventual goal is to produce and stake out as much habitable land as possible for the sole benefit of the colonists on each individual ship. The robots need to upgrade themselves and make do with the resources of the planet as much as possible in order to achieve this goal. Because of this, several enterprising, non-player organizations have set up automated installations in town-like collectives to facilitate surface trade, storage, information dissemination, robot upgrades and repair for a price.

What do I control?
The player controls a single robot on the surface of the planet in third-person view. Players may also be able to save and load multiple robots, just as most massively multi-player role-playing games allow you to have multiple avatars to choose from at log-in. However, a player can only control one robot at any time, unless the player has more than one networked computer.

What is the focus of the game?
Customize your robot and form alliances to achieve your goals. Collect resources and use them as currency for services and other materials. Form a team among allies that you trust. Design and build structures that allow you to traverse and stake out land. Use pre-made equipment wisely and sparingly. Defend your land from opponents. Control the flow of lava on the planet to serve your own purposes.

What is different?
Unlike most other massively multi-player role-playing games, you can actually change and design the environment for your needs on Hephaestus. Unlike most other robot-design games, this game keeps you in constant control of your robot at all times and requires negotiation and cooperation to succeed. No game includes the degree of customization and the possibilities for exploration that Hephaestus offers.

Who is the target audience?
High school and early college gamers form the target market for Hephaestus. However, the content should be accessible to a larger audience. Foreseeable game play involves one player per avatar at one time, although groups can and should collaborate in the design phase of the robots themselves.

What will people learn through playing this game?
The game will involve Physics at the AP and MIT freshman level. It will also encourage engineering approaches in the vein of the US FIRST competitions, which involves multipurpose robots working together to solve a common problem. It must be clear which physics and engineering concepts play a part in a given game play dynamic. For instance, if robots can slide down the side of an inclined rock, players should be able to apply AP-level knowledge of friction to solve this problem.

How will people learn through playing this game?
Game mechanics will reward thoughtful design and articulation of ideas to other players. Trial-and-error approaches to problem solving will likely work but it will not be fun, economical or practical in the long-term to adopt such an approach. Constructivist and goal-based learning allows players to cement physical and engineering principles while playing the game. Players can and should set their own goals when playing the game but they have to apply a series of engineering skills to achieve their aims.

Design Tensions

Design tensions (Wenger, 1998) are ways of thinking through design processes. Listing tensions encourages game designers to anticipate the potential pitfalls in a system and leverage them to create innovation.

Gender.
A game about robots has the capacity to be a very "male" gendered play space. Creating a game that has a cross-gender appeal can be achieved by incorporating game elements that have traditionally appealed more strongly to women. Elements like collaboration, interaction, narrative backdrop, and intriguing gameplay with social dynamics. Such games have also been popular with male audiences historically not interested in the aesthetics and practices common in computer / video games. Putting the game online with plenty of collaboration and interaction is an important first step in opening the game to broader populations. Ensuring that the game has a captivating aesthetic that will not alienate women and / or men not into robots will be a challenge. The story will need to carry some of this workload, as well..

Interactive online narrative.
Many of these activities involve creativity and competition, and as such will be intrinsically rewarding for some. However, without an overriding purpose or narrative tying them together, others will likely find the activity pointless. Designing an engaging dynamic story that players can affect and unfolds in real time will be challenging.

Online-Offline.

Designing robots is fun. Critics might argue that doing such activities in a computer-mediated environment suffers because student lose the experience of interacting with physical robot parts and designing actual robots. We agree. In no way is Hephaestus meant to replace the valuable practices of real-world robot design. However, computer-mediated environments make other, new design practices possible. First, players who might not afford to purchase robot kits, or who might not otherwise ever enter a robotics competition can experience some of the joy of designing and building robots through Hephaestus; you don't need a machine shop to play Hephaestus. We hope that the engaging gameplay will attract a whole new breed of player to robot design.

Second, as a computer mediated environment, players can use the game to engage in rapid prototyping. Players can experiment with different robot parts and see what works and what doesn't in different situations. Further, players can encounter design problems, such as how to move 1 ton boulders or design bridges that would not be encountered in a typical FIRST design competition. Finally players could experiment with expensive parts, possibly designing underwater or flying robots. Ultimately, we see Hephaestus as a complementary extension of offline robot design activities.

Designing Quests.

A key to this game will be designing effective quests, story modules that set local, short-term goals that will shape player interaction and competition." Quests need to be designed so that they force players to grapple with meaningful content. For example, one can imagine that a player on my hill example would intuitively build a robot with a low center of gravity, avoiding the center of gravity issue all together. However, if we design a challenge where there is an object placed on top of a high tower, then players will need to design tall robots and be forced to deal with center of gravity. Quests also need to be designed so that no one player can complete the quest alone. Players will need to rely on one another in order to complete the quests.

Pedagogical.

An issue with this type of pedagogical model is to engage players in thoughtful, intentional design, exploration, and play, as opposed to relatively thoughtless trial-and-error processes. In the First robot competitions, players have a large incentive to get it "right" ñ they only have one chance at competing. In a digital world, there are infinite opportunities to experiment. Hephaestus can utilize the best of both approaches by encouraging deliberate design though limiting access to resources (etc.) but can also create learning opportunities within trial and error experiments by aiding understanding of why particular processes ultimately worked. Another pedagogical approach to learning might be to require intermediate and upper level players to mentor (teach) lower level players. And classroom teachers can reinforce game lessons through requiring more traditional academic work product like design schematics (etc). Like all G2T games, Hephaestus will ship with a teacher's guide that will suggest assignments that teachers could use to supplement the learning experience, such as design schematics, reflection papers, or use quizzes and tests.

User Scenarios

Scenario:

1-20 seconds	Player sees short cinematic of things you can do in this world. Initial Menu: • Settings • Enter World • Robot Design Shop • Install/ Reinstall
30 seconds:	The player is given 2 choices: 1. Choose from a template of archetype robots or 2. Create her own from scratch. The player realizes that she can build her own robot. She is forced to decide what kind of robot she can be and begins to make decisions about what kind of identity she wants to forge in this world. This step can be undone easily.
3minutes:	In game now. Gets a feel for the world. Makes a choice about what direction she wants to explore. Sample choices: • Traverse a large, inviting field • Enter a town • Look behind a large obstacle (i.e. boulder) The player has also encountered some of the basic problems of moving in this universe: center of gravity, water, terrain types. Some low hanging fruit (minerals, coal, etc.) are visible in the field. Thus, the player types (explorers, socializers, achievers, player-killers) all have some options immediately available.
30 minutes:	Player reaches some success in the world – whether it be climbing a hill, talking to another player, or visiting a town.
90 minutes	Player has met other players and weighs the decision of joining an alliance.

As players design their robots, they wrestle with design trade-offs among several variables, including acceleration, top-speed, breaking ability, center of gravity, and torque). Each feature of the game world (weather, day / night, location) corresponds to a specific physics concept (friction, energy consumption, or center of gravity). The following scenarios illustrate how these design trade-offs play out in the game.

New user, 1 minute scenario

After installing the game and watching the introductory animation, the user, Bob, sees a slowly rotating, spaceship view of Hephaestus and its solar system. Text data blurbs periodically appear over the planet, giving information about the planet and the spaceship, reinforcing the feeling that Bob is looking at Hephaestus through a spaceship viewscreen.

Overlaid above this is a menu allowing him to ‘Load design and land robot’, ‘Design and land new robot’, ‘Deploy existing robot’, ‘Scrap existing robot’, ‘Change game options’ and ‘Quit’. Because this is Bob’s first time playing Hephaestus, the game dims the ‘Deploy’ and ‘Scrap’ options. He clicks 'Load design and land robot' and the viewscreen changes into a file-open window, with a prominent option on top marked 'Choose a preset robot'. Because Bob has never designed a robot before, the file-open window is largely blank, and he decides to click 'Choose a preset robot' instead.

The game camera 'looks up' then from the ship's viewscreen to reveal a character dressed in a quasi-futuristic, yet businesslike outfit, known as The Aide. He explains that Hephaestus is largely volcanic but possesses a wide range of different terrain, and the robots sent to the surface need to perform a variety of different tasks that will involve customization. He also states that resources are limited aboard the ship and the robot may need to mine for minerals or trade services in order to afford customization. At this moment, a value of currency appears on the screen, indicating the amount of money currently available to the player. The amount is approximately enough to build and launch three small robots or one large and one small robot, which the Aide mentions.

The camera follows the Aide as he walks over to a high-tech workbench, on which sits four shiny robots. The Aide explains how these prototype robots are based on designs from Earth, and are thus not as sophisticated as robots designed from scratch using technology developed during the long trip from Earth to Rigel Kentaurus. Still, these designs are good starting points and Bob can later customize them using neutral facilities already on the surface of Hephaestus.

The Aide then describes each robot in detail. The Jackrabbit is a cheap, fast scout robot that will not be useful for much other than exploration, given its small chassis. The Mule, on the other hand, is a larger robot that has reasonably good stability and trades speed for capacity. The Beaver is an amphibious robot with inflatable wheels and multiple solar panels for extended range. The Mastodon is burly and expensive but can generate enough torque to hold heavy cargo and to dig its tracks up steep inclines. All the robots have rudimentary mining equipment and a simple scoop to pick up loose material on the ground.

Bob decides that he would like to save money and have a look around the planet first, so he clicks on the Jackrabbit. The Aide picks up the Jackrabbit robot and loads it into a landing capsule specifically designed for entry into the atmosphere of Hephaestus, all the while humming to himself and mentioning some disturbingly affectionate affirmations to the Jackrabbit.

The game camera returns to the viewscreen, which now prompts Bob to register his game as a first-time player. Bob enters his registration information, a user name and a password, which will allow the multi-player server to keep track of his progress from this point onwards. Once he does this, the game connects to the game server and confirms that he has not picked an already-registered username.

Once confirmed, the viewscreen shows a map of Hephaestus. The Aide explains, off-camera, that the image combines both seismic and electromagnetic telemetry from the past 24 hours, revealing actively volcanic areas and zones of high robot concentration on the light side of Hephaestus. The Aide recommends landing near a neutral robot town if Bob is unsure about what to do first. Bob decides to click and confirm a landing zone near a town in the Southern Hemisphere of Hephaestus.

The camera shifts to an external view of the ship, revealing Bob's username, 'Cheesemaster', painted on the outside of the ship. The capsule rockets out of the ship, then extinguishes its slow-burn engine and falls towards the blue planet, gathering speed and glowing red upon contact with the atmosphere. An energetic, orchestral piece of music accompanies a long shot of the capsule streaking through the sky of Hephaestus like a shooting star while the game establishes real-time connections with the game server. Once the connection is complete, the camera shifts to a high-angle shot of the capsule deploying its parachutes, slowing its descent, and finally landing on the planet with a soft bounce. After an awkward pause in the music, the capsule falls apart like a Keystone Cop car, revealing the Jackrabbit inside. The camera rotates behind the Jackrabbit, locking in position in classic third-person view.

Bob has landed on a grassy field on Hephaestus with the town in the distance. He is now ready to begin his explorations.

New user, 5 minute scenario

The screen fills with relevant status information, along with a prompt in the middle that informs that Bob can press 'escape' to 'Abort the diagnostic test', also known as the in-game tutorial. Bob, however, does not know how to play the game, so he elects to allow the tutorial to run. The Aide's voice comes on again, first mentioning that although Bob is still getting used to his controls, other robots in the vicinity may attempt to interfere with his practice. During the tutorial, the Jackrabbit may automatically use jump jets, automatically reclaimed from the capsule, which will allow it to escape from hostile robots.

In addition, an atmospheric electrical storm has knocked out the communication system of the robot for a short while, so it will not be possible to communicate with other robots for a while. This makes it impossible to distinguish friend from foe, thus, the jets will activate when any robot comes into contact with the Jackrabbit.

The Aide asks Bob to test the Jump Jets by hitting 'J', blasting the Jackrabbit several feet into the air and in a random lateral direction, faster than most robots can move on the ground. Once Bob has done this, the Aide begins explaining to Bob how to use the keyboard and mouse to move the Jackrabbit around and change the game camera from over-the-shoulder, spaceship-downwards-zoom and first person view. The Aide also explains that the basic mining and scoop implements require Bob to maneuver the Jackrabbit over the mineral or material in question and press specific keys, hinting at better mining and reclamation options available within the town. The Aide also draws Bob's attention towards various indicators on the screen that list communication range, battery power, speed, and so on.

At this moment, another player spots Bob and realizes from the capsule wreckage that Bob is a new player. Sensing the opportunity for an easy takedown, the other robot charges at Bob. The moment the two robots touch, however, the Jackrabbit rockets into the air with its automatic jump jets. The Aide mentions that the jets seem to be experiencing some unforeseen problems. Still, the Jackrabbit lands a safe distance away from the hostile player and not any further from the town. The hostile player realizes that chasing down a new player with automatic jump jets is more trouble than it is worth and leaves the vicinity.

The tutorial resumes as the Aide describes the rest of the on-screen indicators and explains where further instructions can be found in the town, as a small inset window shows surveillance images of distinctive locations inside every town. The Aide then declares that the communications system is beginning its reboot cycle, and quickly runs through Bob's controls for communication. Once Bob can talk to other players, the tutorial ends and Bob now has the option to head for the town or some other area of the planet.

Bob decides to try the jump jets again, which suddenly release a lot of smoke but fail to launch him in the air. The Aide's voice comes on again and says that he feared that the capsule engines would not last long. He recommends caution when approaching unknown robots, as they may be hostile to new robots on the planet, or their controlling engineers might just be ornery. Bob turns the Jackrabbit around, noticing that the jump jets are now a pile of black scrap lying on the ground where the Jackrabbit was a few minutes ago. He moves the Jackrabbit over the scrap and deploys the scoop. An onscreen overlay confirms he has picked up metal scrap.

Bob then decides to return to the capsule, remembering that there would be more metal there. He notices that the Jackrabbit is not moving so quickly. As he approaches the capsule, he realizes that another group of robots reached the capsule first, tearing its remnants apart with blowtorches and articulated arms. Noticing that the robots are all painted similarly and emblazoned with the words 'Destructo-maniacs', Bob wisely turns around and heads towards the town instead.

Bob begins to pick up sporadic text communications from the robots in and around the town as he approaches it, which mostly appear to be requests for information and trade. Bob realizes that the communications are on the 'broadcast frequency', previously mentioned by the Aide. He surmises that the respondents must be sending their replies directly to the requesting robots via coded channels, and considers the possibility of trying to find some sort of eavesdropping upgrade for his robot. However, he first finds the trading post, which is literally a tall post in the middle of the town, surrounded by articulated arms that load and unload cargo from an endless stream of in-game robots.

Going into a vacant space near the trading post, the trading post immediately broadcasts the necessary commands for trading to Bob's communications system, which Bob receives as a series of short text messages. Bob brings up an inset inventory of the Jackrabbit's storage compartment, selecting the scrap metal and clicking the 'Sell' button. An arm from the trading post extends towards the Jackrabbit and removes the scrap metal, crediting a small amount of cash to Bob's currency meter.

Bob leaves the trading post and heads for the upgrade shop, which resembles a garage. Like the trading post, Bob receives instructions as he pulls up to a vacant lot in the shop. He receives a rude shock upon seeing an inset listing of prices for the upgrades. He notes the availability of communications upgrades that not only allow him to listen in to some coded transmissions but prevent eavesdropping on his own coded transmissions. Unfortunately for Bob, they are extremely expensive. Bob decides to stick to his original plan of having a look around the planet, and decides that solar panels might be a good idea. The panels are more expensive than the scrap he sold earlier but since Bob did not spend all his money building and launching the Jackrabbit, Bob can afford one panel easily.

The extra weight of the panel does slow Bob a little, although the Jackrabbit is faster than it was when carrying the scrap metal. Bob notices that if he drives the Jackrabbit at full speed, his battery gauge drops quickly. Staying still in the sun, however, slowly increases the gauge. Through a little experimentation in the fields around the town, Bob figures out how to maintain a speed that is reasonably quick and does not excessively drain his batteries.

New user, 15 minute scenario

Bob decides to head out towards several hills in the south, after remembering how some broadcasts from the town mentioned mining expeditions in the hills. He maintains a steady pace to the south across an undulating field, noticing that if the Jackrabbit goes too fast over the undulations, it becomes a lot harder to control. In particular, when moving at high speeds, the Jackrabbit tends to continue moving in the same direction instead of turning, whereas it is relatively quick and easy to turn when it does not have any forward momentum.

As the hills approach, Bob notices a river over to his right, and changes heading slightly to have a closer look at it. The water is slow moving and the river is wide. However, the color of the ground suggests that the river might have been wider in the recent past and Bob hopes the river will not obstruct his passage further upstream. As he turns towards the hills again, he realizes that the Jackrabbit's thin wheels are making deep tracks in the sandy soil on the riverbank and accelerating becomes difficult. Yet, after spinning the wheels for a couple of seconds, the Jackrabbit wheels eventually catch on the sand and Bob's robot takes off at high speed, wildly. With much difficulty, Bob gets back on the grass and makes a note not to get too close to flood plains without wider wheels.

The Jackrabbit eventually reaches the foot of the hills, which have a gentle incline and are not too tall. However, they have rocky outcrops dotting its largely grassy surface. The wheels of the Jackrabbit tend to accelerate better on the rock than the grass but this makes the Jackrabbit veer left or right occasionally as it tackles the incline. Bob notices his battery is running down although he is maintaining the optimum ground speed. He slows a little, and as he does so, notices a group of robots a little uphill. Some turn towards him, and hail greetings to Bob over the broadcast channel.

Bob responds with a hello, struggling up to their altitude. They have a brief text exchange, as Bob explains he is a new player. One of the players of the other robots introduces herself as Flood, a member of the Monsoon Collective. There are about six other members of Monsoon, although only there are only four of them logged in. The four robots in front of Bob spread out in several directions and lower mining drills from their machines. Bob asks Flood how they know where to mine. Flood responds that there are rumors that this hill holds a vein of iron ore. However, that group that made the discovery has not been active in protecting the find, possibly because no one has found the richest vein in these hills yet. Monsoon is simply prospecting in a systematic manner. They make a little money from the variable amounts of iron in their samples, so it is not a total waste of time.

Flood suggests not that Bob stay away from the granite protrusions because they will ruin his rudimentary mining equipment in short order, and to concentrate on the soil in between. Bob remarks that they are considerably less hostile that the first robot he met, and Flood replies that Bob not much of a threat to them, being an unaffiliated, new player. Bob asks if Monsoon needs any new members but Flood responds with a negative, although he can help with today's mining. Flood gives Bob a coded broadcast public key that Bob can use at any time. Whenever Bob is within range of a transmission tower, he will be able to hail Flood no matter where she is on the planet, assuming she is logged in. Of course, she may not be within range of a tower herself, making it difficult for her to respond.

Bob decides to start drilling where the ground is undisturbed. As he mines, he notices that his cargo is slowly beginning to fill with iron ore, not soil. He remembers the Aide explaining that the mining equipment automatically separates the ore from soil, maximizing storage capacity. However, the drilling is slow and the soil is rather poor in iron, so Bob moves a hundred meters to the west and drills again. This time, his cargo hold fills faster, although Bob realizes that if he had a larger robot, this would still be a rather slow rate. He broadcasts a message to Flood, who is still within transmission range, that the soil to the west seems richer. Flood and another Monsoon robot head over and begin drilling, verifying Bob's discovery. It is not the mother lode but it will allow them to fill their cargo holds before sundown.

Bob realizes that his solar panel will be quite useless at sundown, which is fast approaching. With a cargo hold full of iron, Bob broadcasts his thanks to Flood and heads down the hill at high speed, although his battery continues to recharge through the solar panel. Bob realizes that it takes considerably more energy to climb a hill than to race down it, although a couple of rough bumps nearly tip his Jackrabbit over and suggest that he should slow down. He arrives at the foot of the hills, noticing that the optimum ground speed is lower than usual but the Jackrabbit is maneuvering much better, probably due to the increased weight of his robot. He turns towards the town and makes his journey back to the trading post.

Seasoned User, 15 minute Scenario

Ana has been playing Hephaestus as part of a classroom activity for a while, and thus, she is already familiar with the world and the workings of the game. She purchases a copy for home use and installs the game, skipping the introductory animation and clicking on 'Design and land new robot'.

The opening viewscreen prompts Ana to register her game, so she enters her registration information but types in her username 'Flood', and password from school. The game connects to the game server and loads up her current amount of game money and her affiliations with the Monsoon Collective, a group of Hephaestus players from her school. However, she does not have any robots designed and stored on her home computer. Thus, she begins creating a robot from scratch.

Once confirmed, the game camera 'looks up' from the ship's viewscreen to reveal the Aide walking over to the workbench, on which sits three different types of chassis. The Aide explains that while the ship does not have the range of customizations available on the planet, multiple functions on the same robot will require a larger chassis. However, moving a large, heavy robot will quickly drain the batteries and limit the traversal range and speed of the robot. He goes on to describe specific advantages of each chassis but Ana decides that she wants to keep things flexible for her expeditionary robot, clicking on the medium chassis. The Aide stops talking whenever Ana clicks.

The chassis appears on the workbench, and the Aide mentions that until the robot is complete, Ana can always reverse a decision by clicking a ‘dismantle last addition’ button, which appears on the screen. He also points out the currency meter has decreased with Ana’s selection. The camera pans over to three different kinds of engines, the larger of which provide increased torque for increased weight. The Aide explains the merits of the different engines, and Ana selects the largest for maximum power.

In a similar fashion, Ana picks a three-speed gearbox, allowing her to switch between 1:1, 1:4 and 1:10 gear ratios, providing fast movement or raw power when the occasion demands. All-terrain wheels add considerable weight to her robot but the engine has power to spare, and Ana predicts that she will need to traverse all sorts of locations, from marshes to mountains. She also picks a diamond-coated drill and two solar panels for long distance prospective mining. All this power comes at a real cost and loss of cargo space, which means that it will take a long time for her to recoup this money from mining alone.

However, she is fully aware that some of her Monsoon associates have hauling robots, the robot equivalent of dump trucks. Other friends have powerful and fast drilling assemblies, for quick extraction of minerals. Ana prefers exploring to mining, as evidenced by the features of her robot ‘Strider’. Her colleagues are quite happy to leave most of the prospective mining to her, especially since hunting for new mineral veins is generally a hit-or-miss affair. Ana intends to add a Thumper to her Strider as soon as she arrives on the surface, which will allow her detect underground rock patterns using low-frequency sound waves.

For now, however, the Strider is ready. Ana completes the design with a Kevlar shell, decorated with a graphic that she loads off her hard drive so that her teammates will recognize her on sight. For that same amount of money, Ana could have launched two medium-sized preset robots but she knows this design is far more useful for her purposes. She confirms and launches the Strider towards the surface, saving the design on her local drive and introducing the Strider to its first taste of Hephaestus atmosphere.

Feature Set

General Features

Hephaestus features an expansive world set on a planet roughly the size of the moon. Players will be on an island that is as big as current games allow (about 25 X 25 miles, or the size of Rhode Island). Players can potentially unlock other islands as expansion packs. Islands can run relatively independently on different servers.

The world will be fully malleable. Objects can be picked up, moved, or placed in an inventory. Objects will be given:

- Mass
- Volume
- Energy Potential
- Properties under extreme heat / cold

Dirt / rocks can be grabbed in chunks of Extra large, large, medium, small and tiny. The logic behind this system is detailed below.

In-Game Housekeeping

When a robot tips over or is otherwise incapacitated, she "calls a cab." Cabs are non-player characters that fly around, righting robots over or towing stranded robots. If a player tips over, she has to pay $5 per ton plus 20 cents per mile away from town. Towing costs 2$ / mile (can you buy these). Other players can become "cabs", if they design appropriate robots. In addition, the player loses time if she tips over. The process of recovering from a tip-over takes 30-120 seconds. If you tip. Camera cuts to flying robot that takes off. The cab finds you via a beacon you have on your robot (can you steal these, could make for funny game play). Players can use this time to tinker in your workshop, watch the world fly by, or research upgrades.

Pedagogical Approach

Hephaestus is predicated on a synthesis of pedagogical approaches. Players learn by an iterative design process where they design a robot, observe how it interacts in the world, making modifications, and then trying out the robot some more. As a community-based game, it is expected that players will also learn from one another, observing other robots, seeing how others have approached similar design problems, and altering their designs accordingly. Finally, players may come together to design persistent structures in the environment, such as bridges, walls, or trenches. This type of work would be collaborative design. See the design tensions section for more background on pedagogy.

The game might be described as employing a community supported constructionist approach (See Amy Bruckman, 1995; 1996). Players learn both through constructing their robots, and by seeing how they function within the world. Thus, players are designing robots not just to pass a test or even win a competition, but also to achieve the goals that they set for themselves in the world.

Assessment

Hephaestus offers several opportunities for assessment. First, playing the game is an example of a performance assessment: Players learning by doing. Potentially, players engage in constant self-assessment in building robots, analyzing their performance, and then modifying their robot. Players can use the communication tools to rate other players' performance in the community.

There are three generally types of assessment that Hephaestus supports in game:

1) Hephaestus will ship with a set of challenges that can be used for assessment purposes. For example, students might be instructed to create an energy efficient robot that will burn X amount of fuel yet be able to travel Y distance. Other challenges can be created.
2) The instructor can set up challenges in the arena for players – challenges that are directly tied to the FIRST competition
3) Instructors can enter the world and set up challenges for players, by dropping off materials at certain way points, or organizing challenges within the game space.

Instructors will be given special accounts so that they may operate without the normal constraints of players; they can traverse to any area in the world, and they will be given limitless supplies of money.

Finally, we anticipate that instructors will have players engage in other assessment approaches in designing their robots, such as building a portfolio of their experience, design papers explaining their robots, or analyses of other robots. Designing such curricular supports will be the role of the curriculum design team.

The Game World

The World is designed with 5 main cities spread throughout the world. Wilderness areas, mountains, deserts, areas of extreme heat, extreme cold, water, and marshlands and are interspersed throughout the world.

Overview

Conceptually, areas might be broken down into the following categories:

a) Towns
b) Useless land
c) Paths/ Highways
d) Wilderness

It is expected that each region may be contested by players, although Wilderness areas should appeal to explorers and player killers.

Five towns will be spread throughout the world. Towns serve as the nexus for resources and communication, as well as a safe space. Areas with the most valuable deposits also have the most volcanic activity and lava surrounding them, so towns cannot be located near resources.

Towns will have the following areas.

- Market place
- recharging station
- arena
  - compete for $$
  - Range of competition
  - Betting balancing mechanism...odds makers
- news center "slashbot" heh.

Arenas are spaces where robots can engage in safe competition. There are design tasks taken straight from past 2.007 Engineering courses at MIT and the FIRST competition in this area. Players might also decide to hold their own competitions here. Wagering for in game materials is permitted.

Game Mechanics

Items

- solar panels
- wheels
- metals
- chases
- gearboxes
- batteries
- motors
- axles

The specifics of these parts are being created and modeled by Woodie Flowers' group.

Energy:

- batteries
- sunlight (solar)
- wind
- volcanic
- solid fuel
- vegetation?

Currencies

- batteries
- coal
- (can coal / mineral conversion become its own economy)
- some form of gold / money

Communications are a critical part of the game. Robots have antennas, and there is a cell phone like network of towers throughout the world.

Specific Features

Projectiles

We want to have projectiles, but this will be a balancing nightmare, potentially.

Autopilots

A suggested add-on is that players create autopilots so that people can have armies of 2-3 robots simultaneously in order to give players opportunities for developing autonomous robots, which would give opportunities for students to interact with computer-programming. These robots might be auto resource gathering robots – miners, or toll both attendants used to guard an area.

Social Networks

As suggested on the design screens, players have a communication interface that gives them access to contact lists. Contact lists communicate:

- If the player is online
- Any group / team affiliation
- The player's relationship to the current game player.
- The player's status within the community

Communication Tools

Players will have access to a chat tool at all times. This may either be text or voice.

Design Screens

Players have access to design screens that they can use to design persistent structures. This design screen is an offline plug-in that:

a) designs structures
b) calculates their costs
c) deploys them into their world

Similar to NetMeeting, players can engage in collaborative designs. They can upload images into the design window, view others windows, and draw on their screens.

Objects

This is not an exhaustive list.

- Lava
- Grass
- Shrubs
- Rocks (5 sizes)
- Few Trees (say 8-10 different types)

Weather

Generally, the weather will be more dramatic than earth. This section of the planet will have a slightly cloudy atmosphere. There will be sun, rain, and all types of precipitation in the world.

Day and Night

There is a day and night. The clock of the planet needs to be determined. Lights will create an interesting game mechanic, however, complicating the power use scenarios.

Water

We would like for there to be aquatic areas in the world. Buoyant robots would float; others would sink. Sinking robots could potentially still work in the water. We may need to flag robots that are not aquatic.

Game Engine

Overview
In general, the game engine works similarly to other Massively Multiplayer games, although it allows users greater control in manipulating the environment. The robots are all created and key aspects are computed offline. These dimensions of the robot's performance are then "black-boxed" and communicated back to the server in game. These dimensions include:

- Rate of acceleration
- Top Speed
- Energy consumption at critical intervals of speed
- Mass
- Torque
- Friction
- Buoyancy
- Center of gravity

Technical Notes
How to create and support a networked world that is highly affected by user behavior is a challenge. We envision the world being built of "bricks". Each brick has properties that are then communicated to the other bricks in the area. Bricks can differ in size.

Damage Models will be a bit difficult, although we anticipate a 3 leveled-model. Destroyed / Broken / Fully Functioning.

Key Physics concepts embedded in robot design:

- torque
- speed
- gears
- energy rates/ consumption
- mass
- wheels/ treads / friction
- buoyancy
- center of gravity

Robots are created offline in "design workshops" Much like the Sims, each robot has information among these 7-8 variables that it communicates to the world. Each variable is created by the interaction of the other parts. These interactions are being modeled by Woodie Flowers' group.

Camera
Camera follows the player over the shoulder. During design screens, a small Picture-in-Picture window appears. There is one standard camera view.

Game Characters

Players are given full control over constructing their robots. However, a few basic templates will allow players to get started in the game. In addition to designing their robots down to the gear, players will be able to customize their skins.

Robot templates:

Each one has a flawed design, which will later motivate the player to go in and learn how the robots work.

a) Rabbit – Bad Gear Ratios
b) Plows -- LandScape Changers – poor torque
c) Battering Rams – similar to plows. Not enough mass
d) Mules – Carry items.
e) Scout – High Center of Gravity
f) Tech Machines – oversized engine

Main archetypes:

The archetypes are the "templates" and specific types of player expression that we want to support. By allowing players to configure their characters by combining parts, we anticipate that players will come up with more diverse types and hybrids. Each starter kit consists of cheaper, less efficient parts.

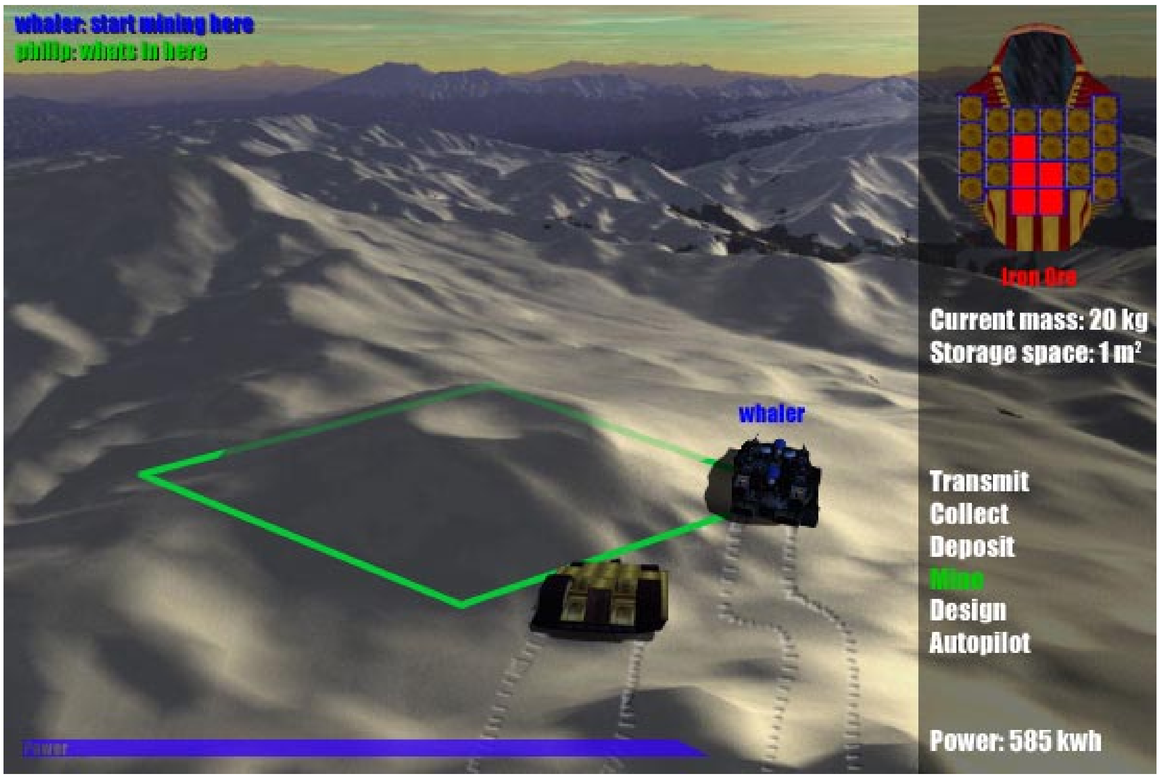
Archetype	***Characteristics***	***Possible design features***
Fast, efficient travelers "Rabbits"	Loose Little Energy; Lightweight	Solar energy Specific gear ratios Wheels (not treads) Battery storage Lightweight
Ground Movers "Plows"	Used to radically transform the environment. May not end up being highly mobile / confined to one space.	
Battering Rams	Hi Torque. Treads. Similar to plows but faster	
Mules	These robots are good at carrying things. Can participate in trade economies. Bail out players once they've tipped over. / Taxis	
Tech Machines (the mage)	Lots of gadgets and ability to process materials.	Ore / dirt separators, arms, hands, misc. gadgets
All Terrain "Scouts"	The SUV	Treads, durable chassis structure.
NPCs	Taxi Cabs	

Players will be given more access to more parts with more money. So, increased opportunities for new parts involve new design trade-offs.

User Interface

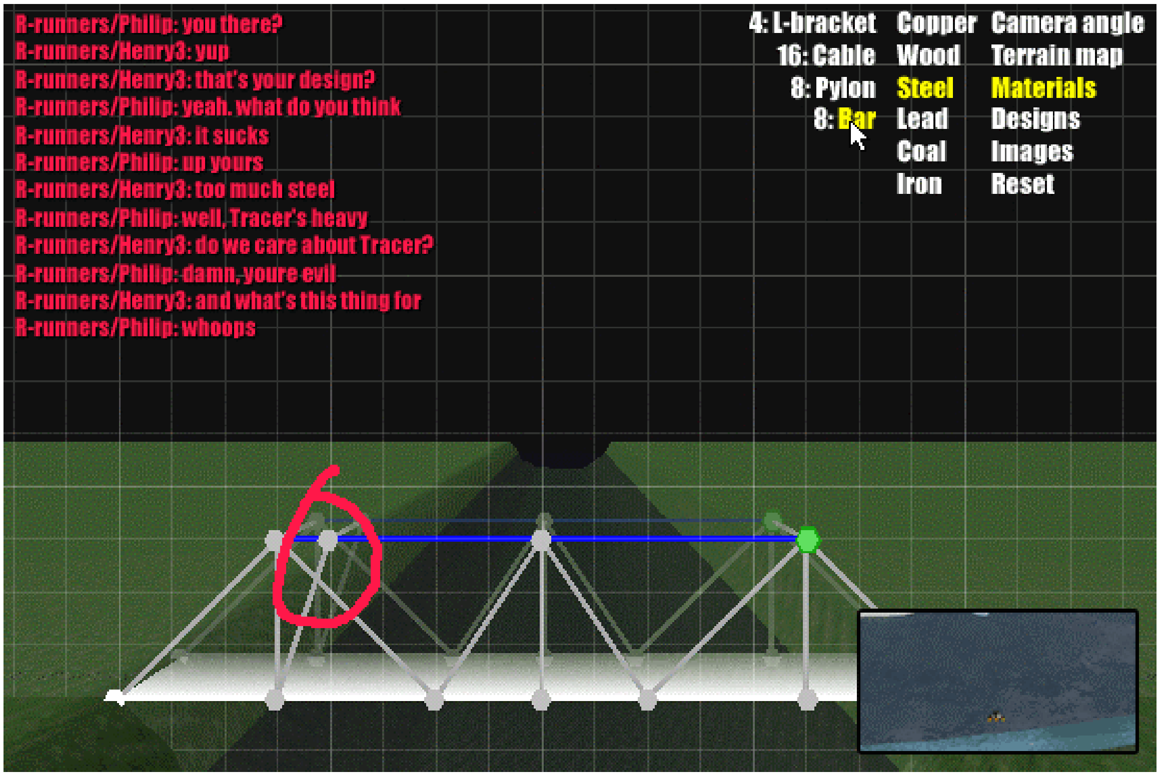
A sample interface is provided below. Players will have a chat window, information on their energy level, an “inventory” screen, their current mass, available storage space, and available power.

User Interface Detail #1



User Interface Detail #2

In game design screens.



Musical Scores and Sound Effects

Overview

The game will have no in game score. There will be environmental sound effects though from lava, wind, and water. Robots will generate sounds as they move and interact with the environment. No plans to integrate sound into the gameplay have been made.

Multiplayer Game

Overview

The game is a massively multi-player persistent world game. However, the game very well could work as a Diablo-style mission –based multiplayer game where players meet in chat lobbies, and then go on constrained missions on the planet. Given the potential size of the planet, this scheme would be consistent with the backstory of the game. For the purposes o f this document, the game will be described as a massively multiplayer game.

Max Players

No present cap on players per server / world, although we imagine that there may need to be caps based on technological performance. The game is designed with roughly 1000 people per server in mind.

Servers

The game is runs on servers, although all design work is calculated at the client.

Persistence

All structures created by players is persistent

Smaller MultiPlayer Version

A second option for the game would be to have students work in small teams (up to 32) exploring different parts of the world on specific missions. This would involve designing specific missions / levels (The game scenarios would be a starting place). This would drastically reduce production costs and implementation concerns.

Math/science engineering / Content

Overview

Hephaestus covers all the material in a 2.007 mechanical engineering course at MIT. The content also cuts across first year collegiate physics and high school physics and materials science courses as well. The FIRST competition is another framework for understanding how this content might be taught in high schools. The design kits are taken straight from the 2.007 course website.

Content

Key Content in lectures in this course includes:

a) Lecture 1: Design is a Passionate Process
b) Lecture 2: Creation of Ideas
c) Lecture 3: Fundamental Mechanical Design Principles
d) Lecture 4: Linkages
e) Lecture 5: Power Transmission Components
f) Lecture 6: Screws and Gears
g) Lecture 7: Force & Torque Sources
h) Lecture 8: Structures
i) Lecture 9: Structural Interfaces
j) Lecture 10: Types of Bearings
k) Lecture 11: Designing with Bearings

Resources

Woodie Flowers
http://pergatory.mit.edu