

Avaneya Crew Handbook

A comprehensive guide for all of our bold contributors.

The Avaneya Crew

last updated 26 May 2011.

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1 Preface

The Avaneya Crew Handbook has several purposes:

1. to define the Avaneya project as clearly as possible so that everyone involved understands it;
2. to provide this project definition in a single canonical location, which is useful when hacking in remote locations with unstable internet access;
3. and lastly, to save those already preoccupied with the project from having to explain the things which are redundant with this handbook.¹

This book is probably not as useful to normal users as it is to contributors. It may even spoil elements of the game for the former. On the other hand, normal users are just as likely to enrich the game through constructive feedback. Constructive feedback is best buttressed when coming from an understanding of the project.

If you pass on this handbook to others, it is probably better to pass a link to it in its original location since it is a living document and will continue to change.

¹ It is usually a good idea to ask questions. But as we say in the hacker community, read the documentation first.

2 The Game

2.1 Why?

Too often, people have come out of experiencing a great dystopian science fiction novel or film, only to say to themselves, Thank goodness we don't live in *that* world.

The problem here is that dystopian science fiction is among the most honest kind of story telling when examined in the context of history. But unless people can see the pedagogical relevance, analogies will remain vague and metaphors cryptic.

But good science fiction is only *partly* fiction because it is the *science* portion that attracts people to it in the first place. Science, by its nature, is a thinking and knowledge oriented enterprise. Science is the study of reality, and yet, fiction is outside of reality. So science fiction is a mediator between the two, often acting as an *avant-garde* for both.

This can set the bar high for what its patrons expect and requires designers to pay a great deal of attention to detail. A certain degree of creative license is expected, but people still prefer it to be as consistent with what we already know to be true, or what is at least reasonably plausible.

Another important reason why this project is necessary is that there is very little, if any, *free*, commercial, games for the GNU operating system. When people use GNU, they are treated as second class citizens in many respects - not least of which is the availability of good games. Not only are there very few higher production titles that are available for GNU, they are usually proprietary, and even then, generally bad ports using deprecated APIs, poorly packaged,¹ and integrate horribly into the user's desktop - ignoring the usual human factors community driven conventions.

In some sense, Avaneya is part of the effort to complete the GNU operating system. This is because "*a complete system needs games too*", once wrote Richard Stallman.²

But in terms of the games' subject matters themselves, they tend to appeal more to the mainstream proprietary user. They do not share the *software libre* community's values of freedom. To them, conscious computing is irrelevant since machines are just tools existing outside of a social context.

Worded differently, the choice between using free and proprietary software is not in the same class of arbitrary choices, like chocolate versus vanilla. Users of free software are qualitatively different from proprietary users. Therefore, a game for that audience should reflect this.

2.2 Classification

People have struggled in the past to classify Avaneya. It is what it is, but the closest traditional categories that form a subset of it are the traditional city builder and management simulations and the real time strategy.

¹ That is, if they even bother to use the platform's native distribution's package manager at all.

² <http://www.gnu.org/gnu/linux-and-gnu.html>

2.3 Who Is It For?

The game so far has attracted a fairly large base of followers. From what can be observed at this time, the game appears to appeal to those with an interest in:

- *challenging the consensus of reality*
- *software libre*
- *a social conscience*
- *science fiction*
- *the interconnectedness of everything*

The game may take place in the future, but it deals with current problems. The best way to get an idea of the intended audience is to quickly see [Chapter 3 \[Understanding Avaneya\]](#), [page 4](#) and to ask yourself the type of audience that those resources would probably resonate with.

2.4 Who Is It Not For?

Avaneya is a *sui generis*.³ It is not like other games, and thus it is not for all people. Those with a brief attention span, believe that things originate in cans with little appreciation for process, and accidentalists will probably not enjoy this game. There are already many such games that appeal to that type of audience, so that need not be our aim here.

This game will challenge you to think, and possibly even offend you. It challenges the consensus of reality, and therefore, potentially, your world view. Consequently, some have accused Avaneya of being a vehicle for culture jamming and political commentary. This project is shamelessly guilty as charged—like the newspapers, film, television, games, and other mainstream media that saturate us.

The only difference is that, unlike those mediums, the very presence of a normative bias in Avaneya is not subject to dispute and is self evident. Other mediums sometimes pretend to not have one. In any case, you would be very hard pressed to try to find any classical work of science fiction, or really any kind of fiction for that matter, that did not. Moreover, that in itself is not necessarily a bad thing.

³ "Literally meaning of its own kind / genus or unique in its characteristics. The expression is often used in analytic philosophy to indicate an idea, an entity, or a reality which cannot be included in a wider concept," (Wikipedia).

3 Understanding Avaneya

A great way to better your understanding of this project is to experience some of the relevant learning resources. You should be able to find all of these resources available either in digital format online, or in physical format at most major book stores. Most of them are not difficult to find.

3.1 Resources For Everyone

These resources are useful for every kind of contributor, from researchers and writers to modellers and engineers.

You might consider reading some of these resources in order to enrich your understanding of the game, whose fabric is drawn from *at least* all of them. The more background knowledge we have, the greater the quality of the game. The same goes for really any kind of complex simulation, and not just Avaneya.

- *Blue Mars: Mars Trilogy Bk. 3*
Kim Stanley Robinson, Voyager, ISBN 9780586213919, 1997.
- *Death by Government*
R. J. Rummel, Transaction Publishers, ISBN 9781560009276, 1997.
- *Debunking 9/11 Debunking*
David Ray Griffin, Olive Branch Pr, ISBN 9781566566865, 2007.
- *Free Software, Free Society: Selected Essays of Richard M. Stallman*
Richard M. Stallman, Free Software Foundation, ISBN 9781882114986, 2002.
- *Green Mars: Mars Trilogy Bk. 2*
Kim Stanley Robinson, Voyager, ISBN 9780586213902, 1994.
- *How to Live on Mars: A Trusty Guidebook to Surviving and Thriving on the Red Planet*
Robert Zubrin, Three Rivers Press, ISBN 9780307407184, 2008.
- *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*
Naomi Oreskes et al., Bloomsbury Press, ISBN 9781596916104, 2010.
- *Minutes of Proceedings and Evidence Respecting the Bank of Canada*
Standing Committee on Banking and Commerce, 1939, pp. 461-500.
- *Open Letter to Minister of Public Safety Regarding 9/11*
Kip Warner, 2011.
- *Red Mars: Mars Trilogy Bk. 1*
Kim Stanley Robinson, Collins, ISBN 9780586213896, 1993.

- *Statistics of Democide: Genocide and Mass Murder since 1900 (Macht Und Gesellschaft, Bd. 2)*
R. J. Rummel, Lit Verlag, ISBN 9783825840105, 1999.
- *Terraforming: The Creating of Habitable Worlds (Astronomers' Universe)*
Martin Beech, Springer, ISBN 9780387097954, 2009.
- *The Case Against Fluoride: How Hazardous Waste Ended Up in Our Drinking Water and the Bad Science and Powerful Politics That Keep It There*
Paul Connett et al., Chelsea Green Publishing, ISBN 9781603582872, 2010.
- *The Case for Mars: The Plan to Settle the Red Planet and Why We Must*
Robert Zubrin et al., Free Press, 1997.
- *The China Study: The Most Comprehensive Study of Nutrition Ever Conducted and the Startling Implications for Diet, Weight Loss and Long-term Health*
T. Colin Campbell, Benbella Books, 2006.
- *The Creature from Jekyll Island: A Second Look at the Federal Reserve*
G. Edward Griffin, American Media, ISBN 9780912986395, 2010.
- *Zeitgeist: The Movie*
Peter Joseph, 122 minutes, GMP LLC, 2007.
- *Zeitgeist: Addendum*
Peter Joseph, 123 minutes, GMP LLC, 2008.
- *Zeitgeist: Moving Forward*
Peter Joseph, 161 minutes, GMP LLC, 2010.

3.2 Resources For Artists

These resources are useful for different kinds of artists, such as 2D artists, audio engineers, cinematic artists, modellers, musicians, and so on.

- *3D Computer Graphics, Second Edition*¹
Andrew Glassner, Green Editorial, ISBN 9781558213050, 1994.
- *Beginning GIMP: From Novice to Professional*
Akkana Peck, Apress, ISBN 9781430210702, 2009.

¹ This book is listed as a resource for artists because it is a wonderful and concise introduction to the theory of computer graphics, but for non-programmers and non-mathematicians. It is a classic, though long out of print. Nevertheless, you can probably find used copies for sale.

- *Blender 2.5 Materials and Textures Cookbook*
Colin Litster, Packt Publishing, ISBN 9781849512886, 2011.
- *Blender 3D 2.49 Incredible Machines*
Allan Brito, Packt Publishing, ISBN 9781847197467, 2009.
- *Blender 3D Architecture, Buildings, and Scenery: Create photorealistic 3D architectural visualizations of buildings, interiors, and environmental scenery*
Allan Brito, Packt Publishing, ISBN 9781847193674, 2008.
- *Blender Studio Projects: Digital Movie-Making*
Tony Mullen & Claudio Andaur, Sybex, ISBN 9780470543139, 2010.
- *Introducing Character Animation with Blender*
Tony Mullen, Sybex, ISBN 9780470102602, 2007.
- *The Essential Blender: Guide to 3D Creation with the Open Source Suite Blender*
Roland Hess, No Starch Press, ISBN 9781593271664, 2007.

3.3 Resources For Engineers

These resources are useful mostly for engineers and other very technical work.

- *Autotools: A Practioner's Guide to GNU Autoconf, Automake, and Libtool*
John Calcote, No Starch Press, ISBN 9781593272067, 2010.
- *Beginning Game Audio Programming*
Mason McCuskey et al., Premier-Trade, ISBN 9781592000296, 2003.
- *Beginning iPhone Games Development*
PJ Cabrera et al., Apress, ISBN 9781430225997, 2010.
- *Design Patterns: Elements of Reusable Object-Oriented Software (Addison-Wesley Professional Computing Series)*
Gamma et al., Addison-Wesley Professional, Hardcover, ISBN 9780201633610, 1994.
- *Game Engine Architecture*
Jason Gregory, A K Peters/CRC Press, ISBN 9781568814131, 2009.
- *Lua 5.1 Reference Manual*
Roberto Ierusalimschy et al., Lua.org, ISBN 9788590379836, 2006.
- *Lua Programming Gems*
Lua.org, ISBN 9788590379843, 2008.

- *OpenGL Library (5th Edition)*
Dave Shreiner et al., Addison-Wesley Professional, ISBN 9780321637642, 2009.
- *Pro OGRE 3D Programming*
Gregory Junker, Apress, ISBN 9781590597101, 2006.
- *Programming in Lua, Second Edition*
Roberto Ierusalimsky, Lua.org, ISBN 9788590379829, 2006.
- *Systems and Models. Complexity, Dynamics, Evolution, Sustainability*
Hartmut Bossel, BoD, ISBN 9783833481215, 2007.
- *System Zoo 1 Simulation Models - Elementary Systems, Physics, Engineering*
Hartmut Bossel, BoD, ISBN 9783833484223, 2007.
- *System Zoo 2 Simulation Models. Climate, Ecosystems, Resources*
Hartmut Bossel, BoD, ISBN 9783833484230, 2007.
- *System Zoo 3 Simulation Models. Economy, Society, Development*
Hartmut Bossel, BoD, ISBN 9783833484247, 2007.

4 Timeline

The world Avaneya takes place in is highly self-referential. A fictional timeline is positioned relative to a *year zero*, with dates preceding suffixed *B.R.*, before the republic; while those following are suffixed *A.R.*, after the republic. This is the method adopted by Arda and his settlers.

Note that a year is defined as a Martian year (MYr) and is not the same as a Terran year. You may want to refer to [Section 7.1 \[Game World Time\]](#), [page 16](#) for a more detailed explanation on how the settlers keep track of time on Mars.

The year zero's placement relative to the Gregorian calendar is deliberately never given. But inferentially, one can reason that it is proximate enough for a contemporary audience to still feel relevant, yet distant enough to afford some reasonable creative licenses.

- **12 Feb 75 B.R.** The last of the *International Space Station* crew return to Earth with the station subsequently decommissioned, deorbited, and incinerated during atmospheric entry.
- **26 June 42 B.R.** The bancor is declared the new global currency and implemented via the respective central banks of the North American Union, European Union, African Union, and Asian Union.
- **13 Dec 39 B.R.** Ramraj discovers a near-Earth, C-type Amor II asteroid, with a size comparable to Phobos from the Lincoln Near-Earth Asteroid Research laboratory, Socorro, New Mexico, North American Union. The discovery is rapidly assigned the designation *52048 Varuna* by the *International Astronomical Union*. His findings are detailed in the *Minor Planet Circular* where he calculates a near collision trajectory with Mars.
- **13 Dec 37 B.R.** Wikileaks publishes a leaked list of 163 purported attendees of the annual Bilderberg conference held three days prior at the Hotel de Crillon, Paris, European Union. Dr. Samuel Lieberman, director of the National Institute of Standards and Technology, and Adriaan Janssen, the Secretary-General of the United Nations, are among those listed.
- **15 Sep 35 B.R.** The United Nations holds the International Mars Summit in Geneva, Switzerland, with the purpose of discussing the options on the table for the first manned mission to Mars. The attendees represent the African Union, North American Union, European Union, Asian Union, along with thousands of scientists, engineers, philosophers, and other scholars from around the world. The minimalistic Mars Direct approach of travelling light, living off of the land, and using indigenous materials to produce the fuel necessary for the journey home is a central theme.
- **28 Sep 35 B.R.** Jacob Kissinger, president of the *Council of Foreign Relations* holds a symposium at the Harold I. Pratt House in New York City, North American Union.
- **3 Oct 35 B.R.** The *Trilateral Commission* holds its biannual meeting several months

in advance, Tokyo, Asian Union.

- **12 Oct 35 B.R.** The International Mars Summit concludes publishing its findings in the *Mars Report*: "*Although the Mars Direct approach is totally feasible, the bar can and should be pushed. The summit determined that it is best to go, not merely for the sake of demonstrating that a safe return is possible, but to establish a permanent settlement on Mars. The purpose being to bootstrap the first non-terrestrial expansion of human civilization for the benefit of all mankind.*"

A preliminary draft of the *Mars Treaty* is produced using a revised *Outer Space Treaty* of 1967 A.D. as a basis for a subset of it. The treaty provides the contractual basis for all signatories, outlining the roadmap, responsibilities, and party resource allocations necessary to serve as a vehicle for the terraformation and first manned mission to Mars operating under a United Nations mandate. The treaty also provides an agreement governing the activities of states on Mars and its two moons, Phobos and Deimos.

The terraformation strategy is to be initiated by intercepting *52048 Varuna* and deflecting it to directly impact Mars using a nuclear warhead. Being a C-type asteroid, it contains high levels of hydrated (water-containing) minerals which, when released into the atmosphere as aerosols, will greatly increase the total available cloud condensation nuclei.

Data was presented at the summit predicting that the direct effect of the introduction of these new dark, carbonaceous, aerosols would be a decrease in albedo since they absorb more solar radiation. This would cause a cascading series of reactions, increasing the mean surface temperature and atmospheric pressure.

While the legalities of the project are defined in the *Mars Treaty*, the international collaborative project it implicates is known as the *Avaney Initiative*.

- **22 Oct 34 B.R.** *United Nations General Assembly Resolution 5571* is adopted making the Mars Treaty ratified. The resolution augments *Chapter III* of the *United Nations Charter* to beget its seventh principle organ, the *Space Agency* (UNSA). It is bestowed with a mandate enacting the treaty, and by implication, the *Avaney Initiative*.

The United Nations Office for Outer Space Affairs (UNOOSA) is dissolved. Its former responsibilities are transferred to UNSA under its new mandate.

The resolution also requires members to accede the North American Union Aeronautical and Space Agency (NASA), European Space Agency (ESA), Asian Aerospace Exploration Agency (AAXA), and all other national member space agencies under centralized UNSA administration. This is granted under the justification that space exploration and settlement ought to be an endeavour for all mankind, best realized through the aggregation of resources.

Lieberman is nominated to the Office of the President of the UNSA, resigning his position as director for the National Institute of Standards and Technology.

- **3 Aug 31 B.R.** The UNSA's Office of the *Avaney Initiative* disseminates more than ten-thousand requests for quotations.
- **17 Jan 30 B.R.** UNSA's Office of the *Avaney Initiative* announces successful bids. The

Iterum Shipyard contract is jointly awarded to Lockheed Martin-Boeing and Mercedes-Pratt & Whitney to build a station in low Earth orbit at a cost of 2.2 billion bancors. The station is to be used as a general purpose interplanetary space vehicle construction platform.

Lockheed Martin-Boeing is awarded a contract to provide three, leased, single-stage-to-orbit (SSTO), manned, re-usable, *VentureStar VII* suborbital spaceplanes. These spaceplanes provide UNSA with heavy lift workhorses for transporting personnel and materials to the *Iterum Station*. They require no external solid booster rockets or external fuel tank and each operate at less than $1/5^{th}$ the cost of the long retired Space Shuttle predecessor.

Mitsubishi-Saab's is awarded a contract to provide the *Avaneya*, constructed *in situ*, at the *Iterum Shipyard*, at a cost of 7.8 billion bancors.

Volvo-John Deere is awarded a contract to provide *Avaneya's* nuclear electric ion-drive propulsion system at a cost of 920 million bancors.

Soros-Murdoch Aerospace is awarded a contract to provide four *Mars Positioning System* satellites and the *Mars Enhanced Telecommunications Orbiter* carrying an optical relay at a cost 750 million bancors.

- **26 July 29 B.R.** Construction of the first completed UNSA funded training facilities in Antarctica and Huelva, Spain, are completed.
- **1 Sept 29 B.R.** Crew selection and training begins at training facilities.
- **B.R.** Crew selection is completed with a broad range of personnel including flight engineers, artificial intelligence specialists with knowledge engineers among them, cyberneticists, chemical and civil engineers, cold weather construction experts, mechanics, biogeochemists, geologists, areobotanists, one xenobiologist, and more. Arda Baştürk is named Mission Commander. United Nations envoy Jacob Kissinger is appointed to accompany the crew.
- **B.R.** *Mars Science Laboratory Curiosity XI*, an unmanned autonomous aerial vehicle, explores potential landing sites for settlement. The integrated on-board artificial intelligence is instructed to evaluate sites based on average available sunlight, water ice, minerology, surface geography, and other factors.
- **B.R.** *Internet Assigned Numbers Authority* allocates A001:CA7:3134::/48 IPv6 address block for Martian use.
- **B.R.** Last rocket leaves UNSA's Cape Canaveral launchpad carrying construction material for the *Iterum Shipyard*.
- **B.R.** *Avaneya* construction is completed *in situ* at the *Iterum Shipyard*, low Earth orbit. The station orbits Earth at an altitude of 340 km, travelling at a speed of 27,400 km/h, and taking one and a half hours to complete one orbital revolution.
- **B.R.** Launched from the Kennedy Space Center, Florida, an SSTO transporting the

Avaneya crew dock with the *Iterum Shipyard*, low Earth orbit.

- **7 Jan 8 B.R.** *Avaneya* completes all system checks and disembarks *Iterum Shipyard* berth. It performs a delta-v from low Earth orbit into a type II Hohmann transfer orbital manoeuvre.
- **B.R.** *Avaneya* crew commence scheduled experiments in space medicine, life sciences, astronomy, physical sciences, meteorology, and human research.
- **7 Jan 8 B.R.** *Avaneya* engages short burn of manoeuvring thruster to performs debris collision avoidance.
- **B.R.** *Avaneya* crew complete all scheduled experiments in space medicine, life sciences, astronomy, physical sciences, meteorology, and human research.
- **27 Aug 8 B.R.** *Avaneya* deploys four *Mars Positioning Satellites* (MPS) into medium Martian orbit.
- **28 Aug 8 B.R.** *Avaneya* aerobreaks into Martian orbit. Instrumentation subsystems update onboard areology database on detailed surface geography, weather dynamics, mineralogy, and more.

Mars Enhanced Telecommunications Orbiter is released and deploys itself into geostationary orbit.

- **29 Aug 8 B.R.** *Mars Enhanced Telecommunications Orbiter* successfully completes self diagnostics and registers itself into UNSA's *Interplanetary Internet* as an available communications node, giving rise to what becomes colloquially known as *Solnet*. Ter-ran downlink passes through a ground station at UNSA's Jet Propulsion Laboratory providing tier 1 network access.

Brokered by a satellite uplink with METO, the *Avaneya* communications team establish contact with Mission Control routed over *Solnet*. *Solnet* becomes the defacto standard for Earth-Mars intercommunication.

- **30 Aug 8 B.R.** Landing site selected. Cargo of mostly construction equipment, hydrogen fuel, water, and other provisions, are jettisoned and parachuted to surface with no material loss, save one asset due to an attitude control computer malfunction.
- **30 Aug 8 B.R.** All crew alight the *Avaneya*, boarding the *Manu* landing craft. The *Avaneya* tracks the critical manoeuvres of *Manu*'s entry, descent, and soft landing at the preselected *Arcadia Planitia* drop site. The communications uplink with Mission Control is maintained throughout over a 4 minute delayed *Solnet* connection.

Crew perform a successful soft landing where they are met with a temperature of -70°C and an atmospheric pressure of 0.030 kPa. Time is local noon, allowing for maximum photovoltaic use.

Team briefings are conducted within *Manu* at the drop site. Concurrently, the recovery team are deployed to recover all assets.

Dynamic isotope power systems are brought online for temporary power.

The construction team begin minor excavation for anchoring and erecting temporary 340 mb rated aluminium strut reinforced inflatable polypropylene tents for the Command Centre and habitats, not requiring a pressurized suit. The greenhouse tent is rated 68 mb sufficient for plant life, but requiring a pressurized suit.

- **3 Sep 8 B.R.** Gas extractors are brought online and run at full capacity capturing liquid oxygen, liquid nitrogen, argon, and carbon dioxide.

Sebatier, RWGS, and methanol gas processors¹ create methane, oxygen, hydrogen, methanol, and aqua successfully.

- **14 Sep 8 B.R.** Recovery team's rovers directed by scouts on methanol motorbikes complete asset recovery of all undamaged parachuted cargo within a 92 kilometre radius from the crew landing site.
- **16 Sep 8 B.R.** On-board artificial intelligence and system firmware is upgraded from UNSA's Jet Propulsion Laboratory over Solnet.

Mechanics team complete the necessary preparation of the backhoes, front loaders, bulldozers, tractors, graders, water ice processors, dump trucks, and other vehicles rendering them available for construction team use.

Mining and excavation operations begin through a mixture of directly manned, remotely manned, and autonomous operation.

- **7 Sep 8 B.R.** Flight engineers issue instructions remotely to *Avaney* to return to Iterum Shipyard from the surface.
- **12 April 8 B.R.** Arda submits himself as a candidate on the ballot for Chancellor of the Republic, accepting it to form the first interim government. Kissinger strongly advises him against this as being unnecessary.

- **[Year Zero] 3 May 0 A.R.** Arda informs the Secretary-General of the United Nations over Solnet in an internationally televised address of the passages of the Rubicon Act, initiating steps to secure the settlement's independence.

The Act declares the colony an independent, sovereign, self-governed, constitutional republic, with a right to self determination. *Article IX* discharges all public debt held by the *International Monetary Fund* and *World Bank* effective immediately. The bancor fiat currency is replaced with a rhodium² standard as legal tender within the republic. Begotten is the *Republic of Arcadia Planitia*, colloquially known as *Arcadia*.

Arda holds an election for populating his cabinet.

- **5 May 0 A.R.** *Arcadia* passes the *Humanoid Act*, stripping corporate legal fictions of the rights of human beings.

¹ See [Appendix A \[Glossary\]](#), [page 62](#) for more information on the Sebatier and RWGS reactors.

² See [Appendix A \[Glossary\]](#), [page 62](#) for more information on rhodium.

- **May 6 0 A.R.** This day is a minimum-energy launch window for Terran inbound. Arda has a security detail escort United Nations envoy Jacob Kissinger to *EVA Bravo*, Earth-bound.
- **6 May 0 A.R.** United Nations Security Council Resolution 12664 is adopted which "*unequivocally condemns in the strongest terms terrorist Martian efforts as a threat to international peace, security, and the spirit Mars Treaty. The Security Council does not recognize the self proclaimed government of the Republic of Arcadia Planitia as legitimate. The Security Council calls upon all members to proactively prevent the regional instability and deteriorating situation of the X settlement*".
The resolution recommends to the *United Nations Department of Peacekeeping Operations* (UNDPKO) that it place all four permanent standing *Rapid Reaction Force* battalions on high alert.
- **19 May 0 A.R.** Selected Rapid Reaction Force personnel are assigned to UNSA training facilities in Antarctica and Huelva, Spain.
- **A.R.** *Yama's* launch window is missed due to low-Earth orbit overly saturated with space debris. UNSA engineers fear they may be approaching the Kessler effect of causing a runaway chain reaction, reducing all objects in orbit. This would threaten the *Iterum Shipyard* and all Terran space exploration. Departure is rescheduled for the next launch window of 25 months.
- **April 5, 1 A.R.** The *Yama*, a manned spacecraft, completes a type I Hohmann transfer orbital manoeuvre, aerobreaking into Martian geostationary orbit.
Yama carries a payload of remotely operated equipment destined for Phobos, as well as a single Rapid Reaction Force battalion. The battalion is to be deployed as the *United Nations Emergency Assistance Peacekeeping Force*. Its numbers are drawn principally from North American Union and European Union airborne light infantry units.
- **April 5, 1 A.R.** *Yama's* Commanding Officer Lieutenant-Colonel Dragov issues warning orders down the chain of command to prepare for insertion, geostationary orbit, Mars.

5 The Characters

Avaney's main characters aim to be rich in detail and multifaceted. Their character attributes are generally revealed through indirect means, such as body language, object symbolism, and dialogue. This may happen during a cinematic sequence, for instance.

5.1 Arda Baştürk

Arda was born 43 B.R., Istanbul, Turkey, to Dursun and Ayla Baştürk. His mother, Ayla, was a bank teller, and Dursun, an aeronautical engineer with the NAUSA Jet Propulsion Laboratory and later military intelligence officer.

Dursun had been active politically in opposing Turkey's membership in the European Union which happened shortly after Arda's birth. Several attempts were made on Dursun's life, culminating in a car bomb that left him paralysed before finally succumbing to his condition a year later.

Ayla was cautious in discussing the identity of the suspected assailants with Arda, as she did not want to risk putting her son in danger. Still, Arda sensed she had suspected that it had not been the work of marginalized extremists, but had been the work of elements within their own government on behalf of the Rothschilds.

As part of a working class family, with only his mother to support him, Arda had few opportunities that would not come without extending great effort on his part.

In an era defined by scarcity, they were of modest means and she felt it important to continue imparting Dursun's philosophy of a positive work ethic. With food shortages rampant, high unemployment, and riots on a weekly basis in Istanbul, she knew it was his only ticket out, if he should have any at all.

Arda was described in his youth as highly perceptive and intelligent, although generally reserved, and further, reserving his intellectual gifts for his principle love, science. With the exception of what little he knew of his father, he felt the political landscape was largely the realm of "*bumbling idiots*". This, combined with his privately held view that the world was irreversibly falling apart, he preferred to devote himself to what was immutable, studying the forces governing the world of natural phenomena.

Arda studied at Istanbul Technical University, made possible through a combination of scholarships and his salary as a part time army reserve officer cadet. He graduated with a degree in aeronautical engineering, 21 B.R, where he was then commissioned into the army as a lieutenant. He completed his research doctorate in heliophysics two years later, completing his habilitation one year later, with rumours he solved a central problem that plagued his habilitation thesis while deployed on a field exercise.

Although wanting to focus on his research, even with his qualifications, employment was scarce and the army reserves was one of the few opportunities available that was stable and left him with enough time of his own. He was well respected in the army as a natural born leader, though his privately held view of the institution was one of resentment, corruption, and misuse.

He later underwent commando training with the 3rd Commando Brigade, Siirt, before being posted to the Mountain and Commando Brigade, Hakkari. He rose through the ranks before acting as the unit's liaison officer, overseeing North American Union troops undergo training at their facilities.

6 The Story

6.1 Background

6.2 Storyboard

6.2.1 Opening Cinematic Sequence

7 The Game World

This chapter deals with some of the different aspects of the world the game takes place in, as one in that world itself might know it as.

7.1 Time

The colonists use a different calendar than on Earth for both practical and political reasons.

Practical, because the Gregorian calendar is useless in a world where the orbital period, seasons, and length of a solar day are different than on Earth. The calendar's months, for instance, are not meaningful in the absence of the natural cycles of the Earth's Moon.

Political, partly because the original Avaneya settlers were predominantly secular, the Gregorian calendar's year zero being incompatible with that; and partly that they desired a calendar which was meaningful in the context of *their own* collective memory.

But as the details go, a Martian hour is the same as a Terran hour, composed of 3600 Terran seconds.

A *sol* is a solar day.¹ This is the Martian analogue to a Terran day, but 2.7 % longer. The conversion of 1.027491 Terran days to Martian sols means that a sol is slightly longer than on Earth. Martian clocks are therefore designed to *time slip* at midnight for 39 minutes, 40 seconds. This allows Martians to use a 24 hour clock which they are accustomed to.

A Martian year, abbreviated MYr, contains 668.6 sols, or 689 days by a terrestrial metric. That means there are 88775.245 seconds in a Martian year with 1.8876712 Martian years for every Terran year (1 year, 320 days, and 18.2 hours).

Three Martian years would be pronounced, "three m-years".

The L_s system is used to designate the solar longitude, the angle Mars makes with respect to the Sun. This is measured from the northern hemisphere with the vernal or spring equinox ($L_s = 0^\circ$). Therefore $L_s = 90^\circ$ is the summer solstice; $L_s = 180^\circ$, the autumn equinox; and $L_s = 270^\circ$ the winter solstice.

There are no timezones. All clocks are set to those of the first settlement location.

¹ A *yestersol* being the sol preceding the current one.

8 Gameplay

8.1 Build Tree

9 Selected Technology

It is generally a bad engineering practise to re-invent the wheel by creating something in a vacuum when there are already many usable components. Avaneya's dependent technology is examined here, grouped by category. It is sometimes explained in their maintainer's own words.

We always try to stick to using free software whenever possible. The only time we might use a non-free tool is to use it as a model in designing a suitable replacement. Another time would be where writing a replacement would be far too difficult and we have no choice.

9.1 Audio

- We use *libmikmod* for playback of tracker music modules. Some people were requesting tracker support, and since it should not take very much effort to integrate into the engine's *AudioManager* subsystem, it seems reasonable. The library also needs to be built thread safe.
- *OpenAL* is used for 3D spatial audio rendering. Actual decoding of audio data is done through other APIs.
- The *SDL* library is used to provide audio decoding through its *SDL_audio* API. It decodes popular formats like Ogg Vorbis.

9.2 Developer Tools

- The *CppUnit* library is a unit testing framework module for the C++ programming language, used only when the engine is built in debug mode.
- The *GNU Autotools* are used to reconcile and harmonize the idiosyncrasies of different platforms. It makes portability far more straightforward than without it.
- The *GNU Compiler Collection* is used for the engine's dependency calculation, compilation, and linking, among other things. Ports of virtually all of its compilers are available everywhere.
- *GNU gettext* is used for localization and translation to different human languages by making it possible to substitute strings that are marked for translation in our C++ code with a string from another language.
- The *libebml* library is the backbone of the Matroska multimedia container format. EBML stands for *Extensible Binary Meta Language*. It is often thought of as a binary analogue to the XML format, though not a complete analogue because, unlike XML, the schema must be known in advance. Therefore, it is ideally suited to be read and written by machines and not humans. See [Section 11.1 \[AresPackages\]](#), [page 23](#) for details on how we are using it in this project.

- The *streflop* library (*STandalone REproducible FLOating-Point*) allows you to control how floating point computations are done in C++. The goal is to make programs give reliable and reproducible results. This is important because differences in machine generated code, numeric handling libraries, dedicated hardware floating point processors, optimizations, and so on, can yield results that are inconsistent across different environments.
- The *xmlstarlet* tool is used to validate XML against a schema. It is useful to check AresPackage manifests and the engine event definition for syntactical errors.

9.3 Graphics

- All modelling is generally done with *Blender*, but modellers are free to use whatever free modelling application they like, as long as it supports common free formats. One popular alternative is *Wings 3D*. Ultimately though, all models have to be importable into Blender since we are dependent on the OGRE 3D exporter for it in order to integrate with the rendering engine.
- *Caelum* is a weather generation plugin for the OGRE 3D rendering engine. It is used to provide weather effects wherever necessary on Mars.
- The *CEGUI* library allows graphical user interfaces to be built on top of the *OGRE 3D* rendering engine. This is necessary for the in game graphical user interface. CEGUI user interfaces are defined through Lua scripts accessing its Lua interface.
- *Hydrax* is a fluid dynamics plugin for the OGRE 3D rendering engine. It is used to provide fluid effects wherever necessary on Mars.
- The *OGRE 3D* rendering engine is a powerful, cross-platform, API generally aimed at game developers. It has a rich and simple to use API with a plethora of plugins available for it. It is strictly a rendering engine and does not, however, cover input, audio, and other standard game engine subsystems.
- The *OpenGL* library provides the rendering backend for the OGRE 3D rendering engine. Although the latter supports other backends, it is very difficult to write and maintain shaders for all of them. OpenGL is ubiquitous these days, can do virtually everything Direct3D can, and does not hold you hostage to any specific platform.
- The *OpenGL Extension Wrangler Library* (*GLEW*, helps in querying and loading OpenGL extensions. It provides efficient run-time mechanisms for determining which OpenGL extensions are supported on the target platform. All supported OpenGL extensions are exposed in a single header file, which is machine-generated from the official extension list.
- *Terrain* is another plugin for the OGRE 3D rendering engine allowing for, as the name suggests, terrain generation.

- The *SDL* library is used to provide image and font loading through its *SDL_image* and *SDL_pango* APIs respectively.

9.4 Input

- The *SDL_haptic* API is used for providing force feedback, provided the API is available and the user's input device supports it. SDL version 1.3 or greater is required.
- The *SDL_input* API is used to provide input handling.

9.5 Networking

- The *ENet* library provides the low level library which Avaneya's mutliplayer protocol is built upon. Its purpose is to provide a relatively thin, simple and robust network communication layer on top of UDP (User Datagram Protocol). The primary feature it provides is optional reliable, in-order delivery of packets. It omits certain higher level networking features such as authentication, lobbying, server discovery, encryption (which we provide via GnuTLS), or other similar tasks that are particularly application specific so that the library remains flexible, portable, and easily embeddable.
- The *GNU Transport Layer Security Library* (GnuTLS) is a free software implementation of the SSL and TLS protocols. It is used to provide encryption at the application level to make it more difficult for an uninvited third party to be a nuisance.

9.6 Operating System

- *Apport* intercepts program crashes, collects debugging information about the crash and the operating system environment, and sends it to us in a standardized format by integrating directly into Launchpad. It is available only on supported GNU operating systems.
- The *D-Bus* (Desktop Bus) API is a simple inter-process communication (IPC) system for software applications to communicate with one another. Avaneya can use it to determine the state of the user's network connection, among other things. It is available only under supported POSIX compliant operating systems.

9.7 Physics

- *OgreBullet* is a plugin adding physics support to the OGRE 3D rendering engine. It is built upon *Bullet*, a free physics engine featuring 3D collision detection, soft body dynamics, and rigid body dynamics. It is used in games, and in visual effects in movies.

9.8 Scripting

- The *libtolua++* library is used to integrate our C++ code with Lua. It is an updated

replacement to the older toLua tool. It makes it possible for engine code to invoke Lua code, and vice versa.

- *Lua* is used to provide scripting support to the AresEngine. The runtime environment needs to have *package.loadlib* present.
- The *lua-gettext* API is a Lua package that acts as a Lua wrapper for gettext bindings.
- The *lua-xgettext* tool is a small program for message extraction of marked strings from Lua code so they can be made available for translation to other languages. It is similar to *GNU xgettext*, but far more primitive; it just extracts the strings and prints them out, without any additional information. It was written, because GNU ‘xgettext’ did not support Lua at the time.

10 Information For Everyone

10.1 Socioeconomic Modelling

Avaneya relies heavily on actual scientific research to substantiate the quantitative models it encodes.

The Equality Trust is an organization that aims to reduce income inequality through a programme of public and political education designed to achieve a widespread understanding of the harm caused by income inequality, public support for policy measures to reduce income inequality, and the political commitment to implementing such policy measures.

The research it has aggregated powerfully reasserts the view that poverty, despair, and crime are not accidents, are well predictable, and that this is obvious by their asymmetrical spatial distribution. The research suggests that there is no such thing as human nature, but only human needs, and consequently human behaviour.¹

The Equality Trust supports this conclusion by providing an invaluable repository of research that lays the foundation for the quantitative models necessary for a simulation like Avaneya.

<http://www.equalitytrust.org.uk/resources/publications>

¹ See *Zeitgeist: Moving Forward* in [Section 3.1 \[Resources For Everyone\]](#), page 4.

11 Information For Engineers

11.1 AresPackages

11.1.1 Purpose

The AresEngine uses a custom game archive format built using EBML, an extensible language akin to XML, but tailored to handling binary data. The Matroska multimedia container is its most prominent client.

You might be wondering why a game engine requires its media to be delivered to it in a custom archive format, as opposed to being exposed "naked" directly through the platform's native file system. There are a number of benefits to using a custom archive format, as well as EMBL specifically.

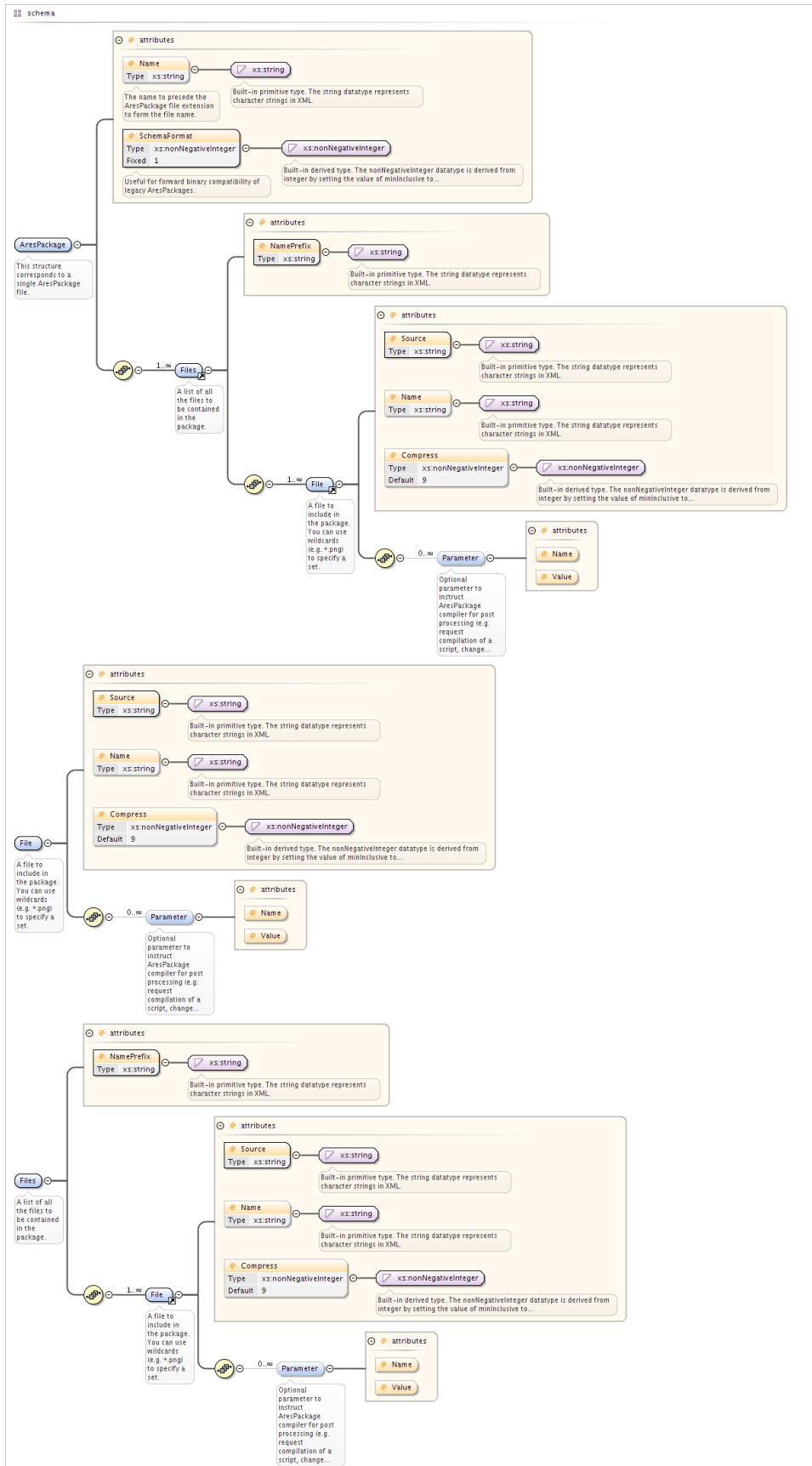
- The EMBL format enables extendability for future format changes.
- It can be easier to distribute a few files containing many, than many to the end user.
- As a single file (*.AresPackage), file seek, open, and load times are reduced.
- Providing a layer of abstraction between the actual raw data and the client that requires it allows us to decompress compressed data on the fly. This results in a smaller file, which means a faster disk to RAM transfer. Remember that the disk is slow, while the CPU is much faster.

11.1.2 Usage

The *ares-package* tool takes a package manifest file (XML) describing the contents of the package to output. The tool archives the requested files, along with whatever settings that may be required, and outputs the package.

11.1.3 Design

A package manifest is checked against an XML schema (AresPackage.xsd) to verify it is syntactically correct. AresSamplePackage.xml is a sample package. The following diagram is a graphical representation of the schema.



11.2 Coding Standards

Try to abide by the project coding standards whenever possible. It is easier to adapt to a new coding standard in a project when that standard is uniformly applied to it, as opposed to where everyone applies their own. Try to apply the following conventions whenever working in C++, as well as whatever is practical to carry over to shaders, scripts, and elsewhere.

11.2.1 Legal

Headers (*.h), implementations (*.cpp), and other code, as defined under [Chapter 13 \[Licensing Rationale\]](#), [page 60](#), should have prefixed the following legal notice. Adapt the syntax for comments as necessary for the given machine environment (e.g. shader, makefile, etc.).

```
/*
    AresEngine, a 3D game engine.
    Copyright (C) 2011 Kshatra Corp <kip@thevertigo.com>.

    Public discussion on IRC available at #avaneya (irc.freenode.net)
    or on the mailing list <avaneya@lists.avaneya.com>.

    This program is free software: you can redistribute it and/or modify
    it under the terms of the GNU General Public License as published by
    the Free Software Foundation, either version 3 of the License, or
    (at your option) any later version.

    This program is distributed in the hope that it will be useful,
    but WITHOUT ANY WARRANTY; without even the implied warranty of
    MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
    GNU General Public License for more details.

    You should have received a copy of the GNU General Public License
    along with this program. If not, see <http://www.gnu.org/licenses/>.
*/
```

11.2.2 Mathematical

- All angles should be worked with in degrees, not radians, whenever possible.
- All floating point calculations should be done in single precision whenever possible.

11.2.3 Formatting

- English (Canadian) should be used for everything non-localized and saved in UTF-8 whenever possible.
- Always use spaces and not tabs. You can use the latter, if you like, but just as long as your editor converts them to spaces when saving.
- Each level of nesting should be indented by four spaces. The exception to this is when a prefix operator precedes an identifier, in which case it should be indented so that the identifier begins at a four space interval.

Right:

```
float SomeFunction()
{
    int i = 0;
    ++i;
    return 1.0f;
}
```

Wrong:

```
float SomeFunction()
{
    int i = 0;
    ++i;
    return 1.0f;
}
```

- You do not need to indent to accommodate a namespace when an entire source file is enclosed within one. If only part of the source is enclosed in a namespace, then those parts affected should be indented.
- An opening brace appears on the next line as preceding code.

Right:

```
float SomeFunction()
{
    for(int x = 0; x < 100; ++x)
    {
        ...
    }
}
```

Wrong:

```
float SomeFunction() {
    for(int x = 0; x < 100; ++x) {
        ...
    }
}
```

- Put spaces around binary operands

Right:

```
A = X + Y;
if(X == Y)
    ...
```

Wrong:

```
A = X+Y;
if(X==Y)
    ...
```


- There is no space between unary operators and the affected variable's name.
- When accessing an array, there is no space between the array name and the opening left bracket.

Right:

```
int n[100];
y = n[3];
```

Wrong:

```
int n [100];
y = n [3];
```

- The if, for, and while keywords are not followed by a space separating them and the left parenthesis.

Right:

```
if(x == 4)
    return;
```

Wrong:

```
if (x == 4)
    return;
```

- When declaring variables, align the variable names on the same column evenly divisible by four.

Right:

```
int      Count;
bool     Complete;
Window   MainWindow;
```

Wrong:

```
int Count;
bool Complete;
Window MainWindow;
```

- When calling a function, definitions and function declarations should have no space between the function name and the following left parenthesis.

Right:

```
int Add(int a, int b)
{
    ...
}
```

```
int i = Add(4, 5);
```

Wrong:

```
int Add (int a, int b)
{
    ...
}

int i = Add (4, 5);
```

- When calling a function or making a function declaration, no space appears after the left parenthesis or before the right parenthesis.

Right:

```
foo(x, y);
bar(z);
baz();
```

Wrong:

```
foo( x, y );
bar( z );
baz( );
```

- A brace preceding or following an else keyword appears on the same line as the else. A statement following an else keyword appears on the same line as the else.

Right:

```
if(x == 4)
{
    ...
}
else
    ++y;

if(x == 4)
{
    ...
}
else
{
    ...
}
```

Wrong:

```
if(x == 4) {
    ...
}
else ++y;

if(x == 4) {
    ...
} else ++y;

if(x == 4) {
```

```

        ...
    }
    else {
        ...
    }

```

- A brace preceding a catch keyword appears on a separate line as the catch.

Right:

```

    try
    {
        ...
    }

    catch(Error SomeError)
    {
        ...
    }

```

- A value in a return statement is parenthesized where it contains more than one term.

Right:

```

    return x;
    return (a + b);

```

Wrong:

```

    return (x);
    return a + b;

```

- If the body of an if, for, while or similar statement consists of a single statement, the statement does not need to be surrounded by braces.

Right:

```

    if(x == 3)
        ++x;

```

11.2.4 Naming

- Do not use Hungarian notation. We prefix objects to denote scope only.

Member of a global namespace:

```
g_Wheels
```

Member of a structure or class:

```
m_Wheels
```

Static member of a structure or class:

```
ms_Wheels
```

- Class and object names should be intuitive, try to avoid abbreviations, and each word should begin with a capital letter. Modern storage mediums can afford to spare brevity, allowing for greater clarity.

Right:

```
// Class for abstracting a camera interface...
class Camera
{
    ...
};

// Create a camera...
Camera LogitechCamera;
```

Wrong:

```
class cam
{
    ...
};

cam log;
```

11.2.5 Structure

- Source lines may be up to 100 characters long. (You can configure gedit to display a margin at 100 characters; that may help you follow this convention.)
- Functions or methods should be broken down into other functions or methods if they get too long and this is reasonable to do.
- Use *assert()* to check your assumptions for things that ought to always be true. Do not abuse it for situations where it is reasonable for a condition to not be true, such as a socket connection failure or a file that could not be opened.
- Follow the *GNU Coding Standards* as much as reasonably possible, save the code formatting points made in this handbook. There is a great deal of wisdom in it.
- A comment which indicates task which needs to be done at some point should look like this:

```
// TODO: Check portability here...
```

11.2.6 Comments

- All comments should be written in Canadian English since nearly all programmers in all countries can read that. If you cannot do that, write them as best you can and have someone help you rewrite them.
- Comments should begin with a single space, then a capital letter and end with a trailing ellipses.

Right:

```
// Load the image...
GrayImage = cvLoadImage(Path.mb_str(), CV_LOAD_IMAGE_GRAYSCALE);
```

Wrong:

```
GrayImage = cvLoadImage(Path.mb_str(), CV_LOAD_IMAGE_GRAYSCALE); //load the image.
```

- The farther left the comment, the higher level and abstract what you are trying to do is. The farther right, the more detailed they are. You can think of a given level of indentation as elaborating on how to carry out what was described at a higher (less indented) level. It should be possible in many cases to strip away all the code, except the comments, and still understand what it is that you were trying to do.

Before:

```
// Analyze single image...
void AnalysisThread::AnalyzeImage(wxString Path)
{
    // Variables...
    IplImage *GrayImage = NULL;
    wxString TempString;

    // Reset the tracker, if not already...
    Frame.Tracker.Reset(0);

    // Load the image...
    GrayImage = cvLoadImage(Path.mb_str(), CV_LOAD_IMAGE_GRAYSCALE);

    // Failed to load media...
    if(!GrayImage)
    {
        // Alert...
        wxLogError(wxT("Unable to load image."));

        // Abort...
        return;
    }

    // Feed into tracker...
    Frame.Tracker.Advance(pGrayImage);

    // Cleanup gray image...
    cvReleaseImage(&GrayImage);
}
```

Stripped:

```
// Analyze single image...

// Variables...

// Reset the tracker, if not already...

// Load the image...

// Failed to load media...
```

```
// Alert...  
  
// Abort...  
  
// Feed into tracker...  
  
// Cleanup gray image...
```

- A single blank line should appear between each pair of functions or methods.
- Do not use a blank line after an opening brace or before a closing brace.
- Do not use duplicate blank lines.

11.2.7 Developer Tools

You are welcome to use any editor or IDE you like, provided it does not require non-standard IDE-specific project files. See [Section 9.2 \[Dependent Technology Developer Tools\]](#), page 18 for a list of all of the developer tools that are required for the project.

11.3 Architecture

The *AresEngine* is responsible for delivering Avaneya. It is designed by the Avaneya crew to provide for the game, but kept architecturally general enough to lend itself to other projects of similar technical requirements (e.g. a city builder / real time strategy genre). If you do not know what a game engine is, Jason Gregory's book *Game Engine Programming*,¹ is highly recommended.

The AresEngine is divided up into many subsystems, each responsible for a given logical task. These include audio, responding to input devices, updating the graphical user interface, artificial intelligence, and so on.

Umbrello was used to come up with the architectural design. At this time, you may need to use the latest Umbrello built from source because the task at hand was so demanding, only Umbrello's bleeding edge was able to handle it. Unfortunately the pre-compiled binary available in most distributions had many show stopper bugs in it that would have made work impossible. Even building from source, it still has many problems. Nevertheless, it was the most mature and functional free design tool available at the time and may still be. We are very grateful to the Umbrello crew who were especially helpful in fixing bugs as they were discovered through the engine design stress testing it.

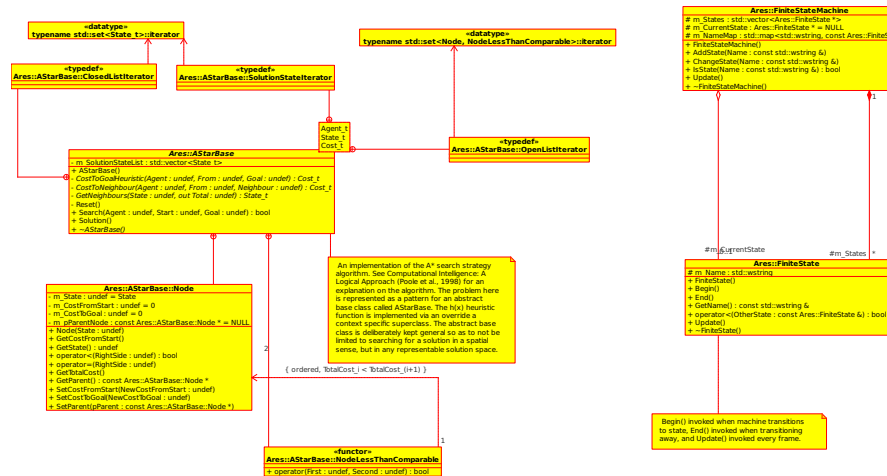
The following architectural diagrams were pulled from the AresEngine's Umbrello project file automatically at the time this handbook was compiled on 26 May 2011.

¹ See [\[Resources for Engineers\]](#), page [\[undefined\]](#) for details.

11.3.1 Artificial Intelligence

This diagram concerns itself with useful artificial intelligence algorithms, though not of an entire subsystem itself.

It contains an implementation of the A* search strategy algorithm.¹ The problem here is represented as a pattern for an abstract base class called *AStarBase*. The $h(x)$ heuristic function is implemented via an override a context specific superclass. The abstract base class is deliberately kept general so as to not be limited to searching for a solution in a spatial sense, but in any representable solution space (e.g. time, language, etc.).



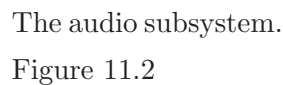
The Artificial Intelligence subsystem.

Figure 11.1

¹ See *Computational Intelligence: A Logical Approach*, Poole et al., 1998 for an explanation on the algorithm.

The *AudioManager* subsystem is responsible for all tasks related to audio. Audio playback is divided into streaming and static audio sources. Streaming sources need to be continuously updated by loading new data from disk, decompressing it, and playing it. A common example would be music or narrative. Static sources are usually smaller and only need to be played once before being freed. Static source examples would be things like the sound of an object contacting another.

Playback is accomplished through OpenAL.

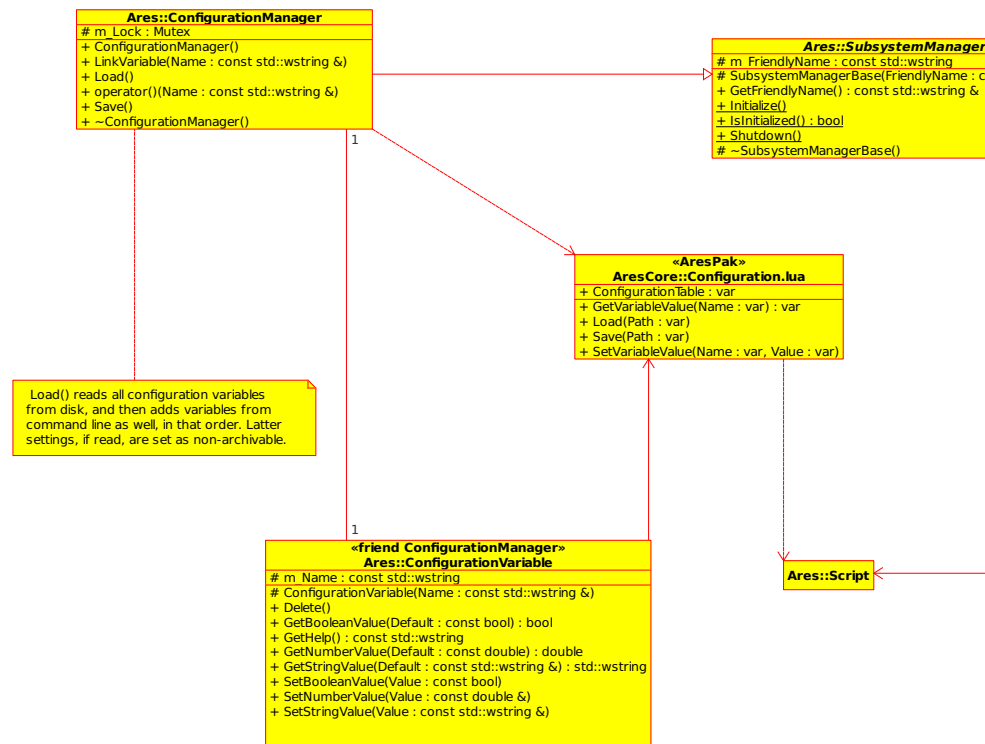


11.3.3 Configuration

The *ConfigurationManager* subsystem is responsible for storing all user configuration. Its *Load()* method reads all configuration variables from disk, and then adds variables from command line as well, in that order.

Latter configuration variables read are set as non-archivable. A non-archivable configuration variable is one that is not saved to disk.

Much of the manager is implemented in Lua because of its excellent database handling.



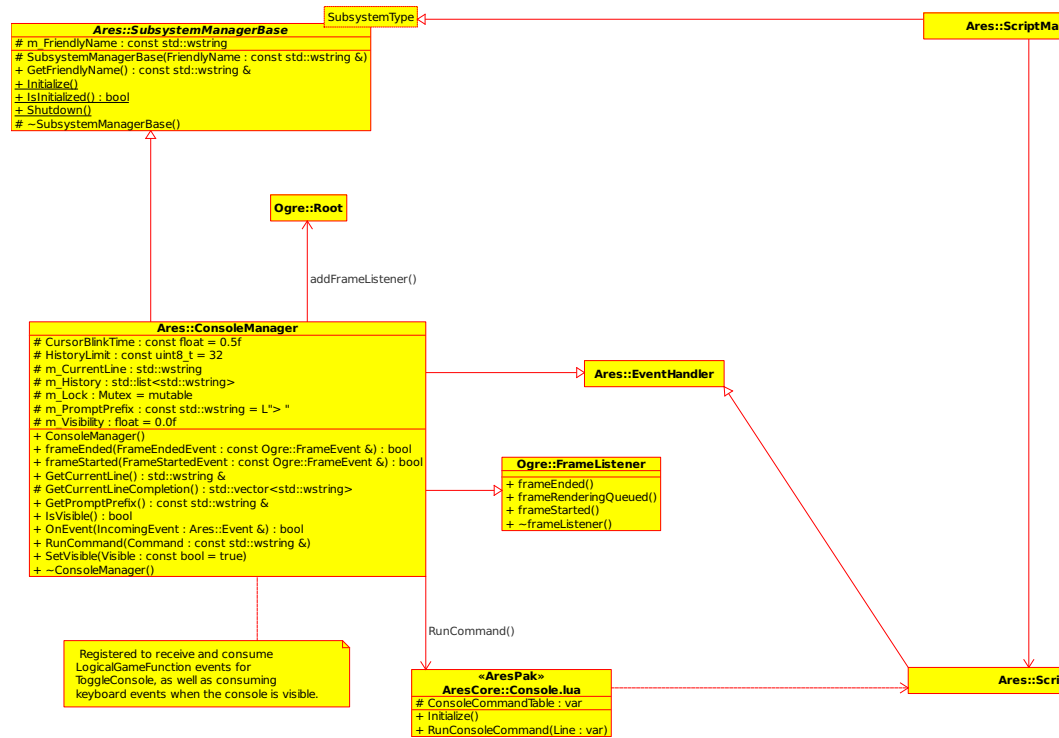
The configuration subsystem.

Figure 11.3

11.3.4 Console

The in game console allows users to access aspects of the game engine at runtime. This is useful for debugging or other purposes.

Console commands are implemented in Lua.



The console subsystem.

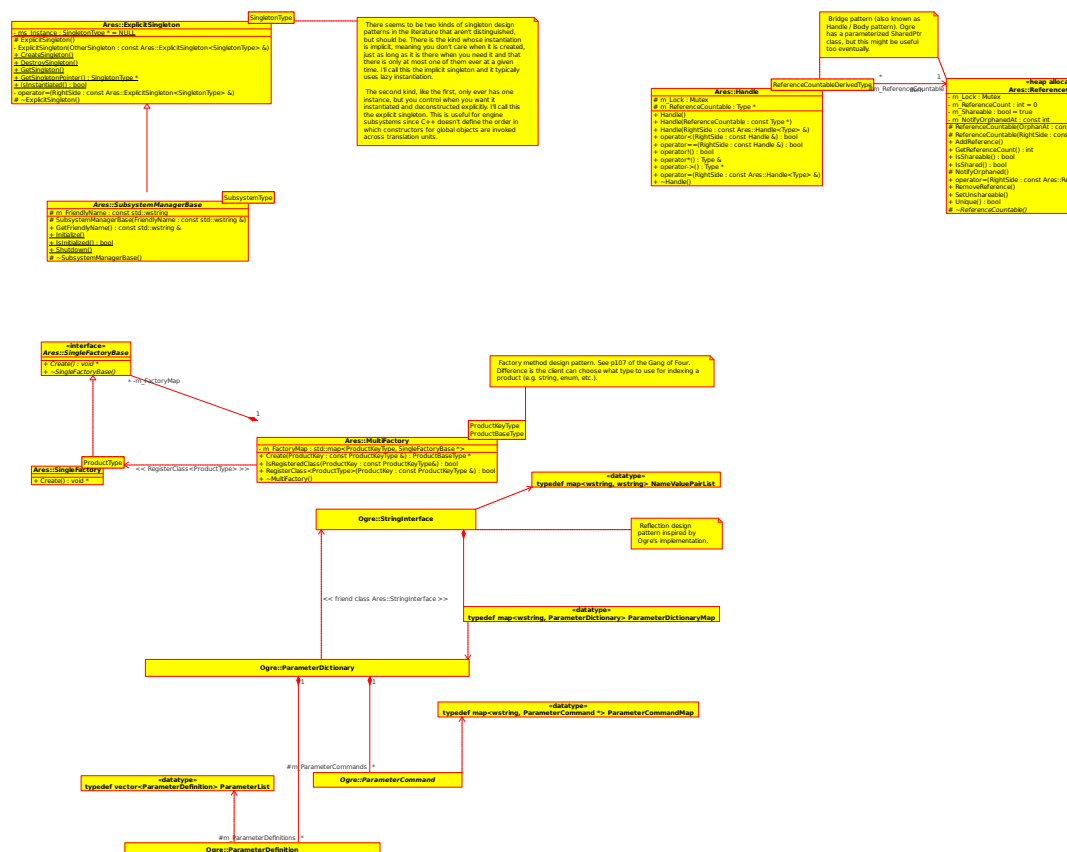
Figure 11.4

11.3.5 Design Patterns

This diagram contains a number of common place design patterns found in many software projects, such as the singleton and multi-factory.

There seems to be two kinds of singleton design patterns in the literature that are not distinguished, but should be. There is the kind whose instantiation is implicit, meaning you don't care when it is created, just as long as it is there when you need it and that there is only at most one of them ever at a given time. We refer to this as the *implicit singleton* and it typically uses lazy instantiation.

The second kind, like the first, only ever has one instance, but you control when you want it instantiated and deconstructed explicitly. We refer to this as the *explicit singleton*. This is useful for engine subsystems since C++ does not define the order in which constructors for global objects are invoked across translation units. This is important to consider, given that the order of subsystem initialization is very important (e.g. resource management must precede audio management).

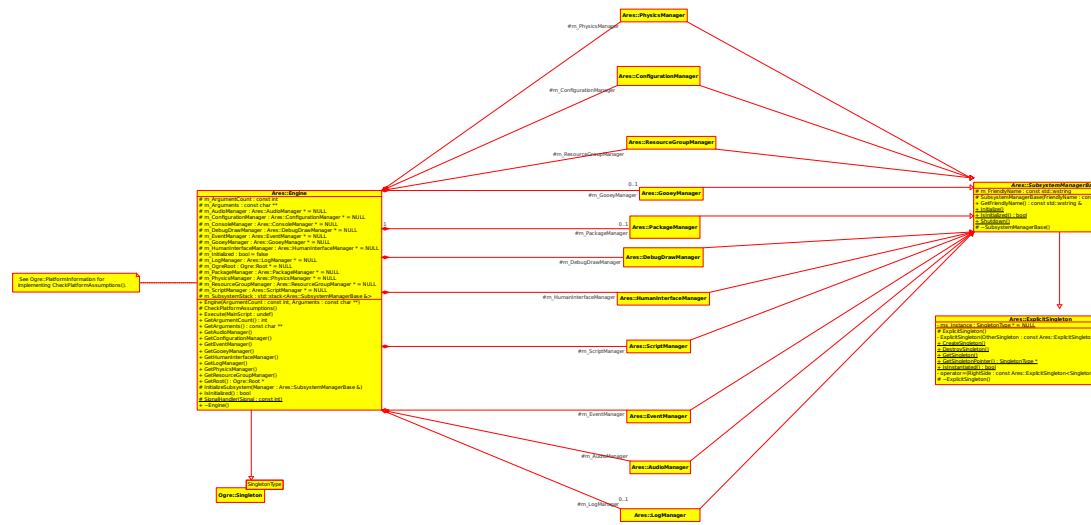


Useful design patterns.

Figure 11.5

11.3.6 Engine

This diagram captures the engine at the highest level and provides an overview of all components in the most abstract sense.



The engine overview.

Figure 11.6

11.3.7 Events

The *EventManager* is responsible for intercommunication between various engine components and scripts. The steps for working with events are as follows.

An event handler can either contain an *Ares::EventHandler* class, or can derive from it and override the *OnEvent()* method. It registers interest in one or more events via the *Register()* method:

```
EventHandler::Register("some_event");
```

Next, to create and enqueue an event, one would do as follows:

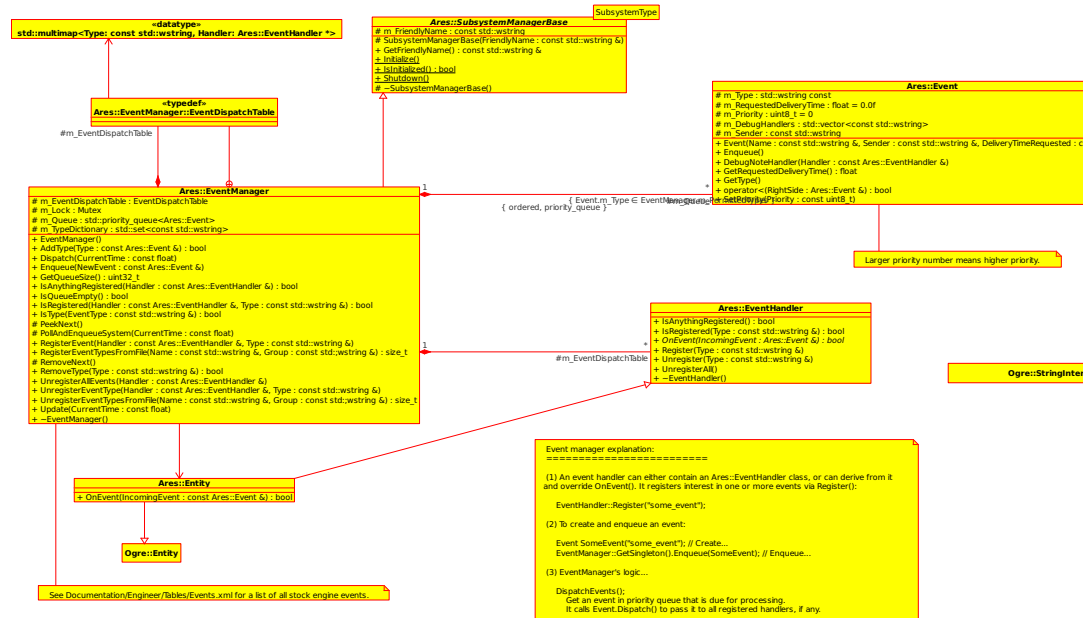
```
// Create a some_event event...
Ares::Event SomeEvent("some_event");

// Enqueue event...
Ares::EventManager::GetSingleton().Enqueue(SomeEvent);
```

Every frame, the *EventManager::DispatchEvents()* method is called to pump the message queue. It will get an event from the internal priority queue that is due for processing. Once an event is fetched, it calls *Event.Dispatch()* to pass it to all registered handlers so that they may do whatever it is that they would like to do when that event occurs.

Events.xsd defines the XML schema that the engine uses at runtime to check builtin event types (Events.xml) against. This is done to ensure the event types defined are syntactically correct and self documenting.

Events.xml contains a list of built-in event types, game engine mod agnostic, for fundamental event types. These include things like input device and window manager events.



The event subsystem.

Figure 11.7

11.3.9 Gooney

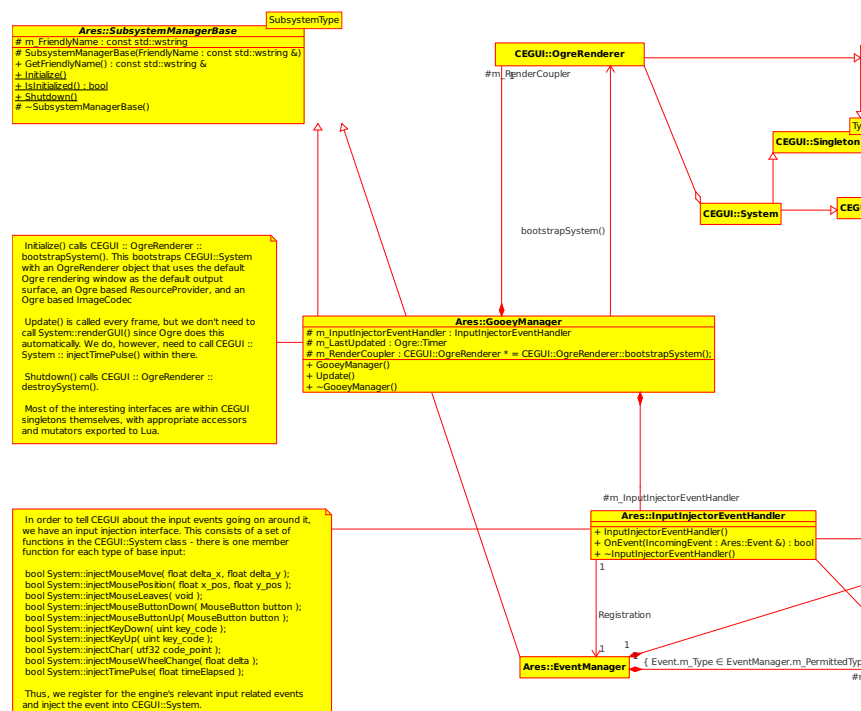
The *GooneyManager* is responsible for managing all graphical user interface overlays and user interaction with them. Its underlying functionality is provided by CEGUI which integrates well into OGRE 3D.

GooneyManager::Initialize() calls *CEGUI::OgreRenderer::bootstrapSystem()*. This bootstraps *CEGUI::System* with an *OgreRenderer* object that uses the default Ogre rendering window as the default output surface, an Ogre based *ResourceProvider*, and an Ogre based *ImageCodec*.

Update() is called every frame, but we do not need to call *System::renderGUI()* since Ogre does this automatically. We do, however, need to call *CEGUI::System::injectTimePulse()* within there.

Shutdown() calls *CEGUI::OgreRenderer::destroySystem()*.

Most of the interesting interfaces are within CEGUI singletons themselves, with appropriate accessors and mutators exported to Lua.

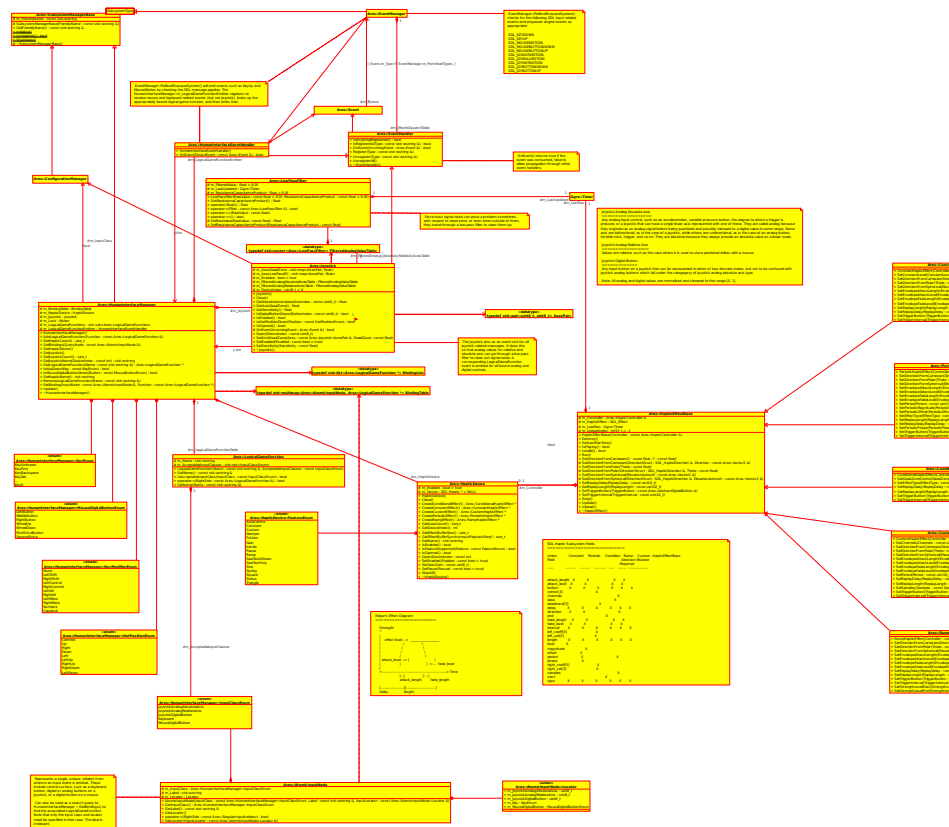


The graphical user interface subsystem.

Figure 11.9

11.3.10 Human Interface

The *HumanInterfaceManager* takes care of routing all events from input devices to the appropriate code that has registered to be notified of that event. In that sense, the manager is mostly unidirectional, but also allows to send information the other way back to the input device if it supports a haptic interface (sometimes called force feedback).

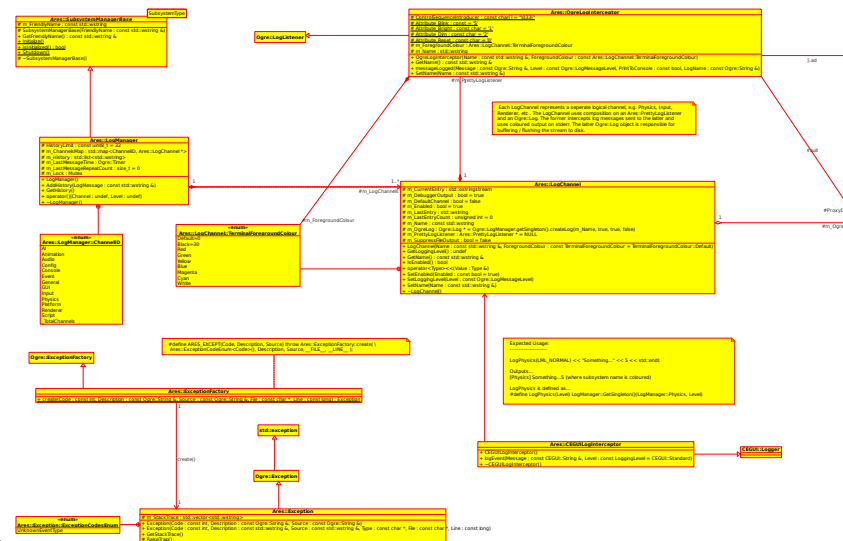


The human interface subsystem.

Figure 11.10

11.3.11 Logging & Error Control

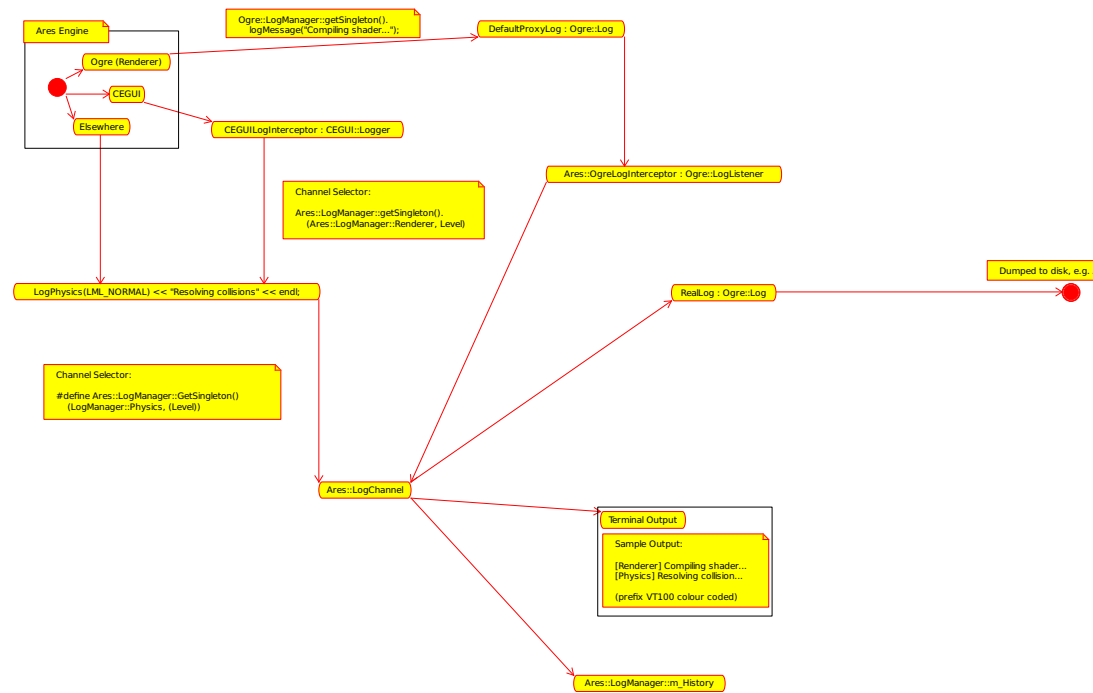
The *LogManager* is responsible for providing a central logging subsystem for all the other subsystems.



The logging and error control subsystem.

Figure 11.11

Since message can be emitted from any number of places, such as within the engine, or within some other externally linked component, such as CEGUI or OGRE, messages have to be intercepted and channeled through the *LogManager*. The following diagram makes this more clear.

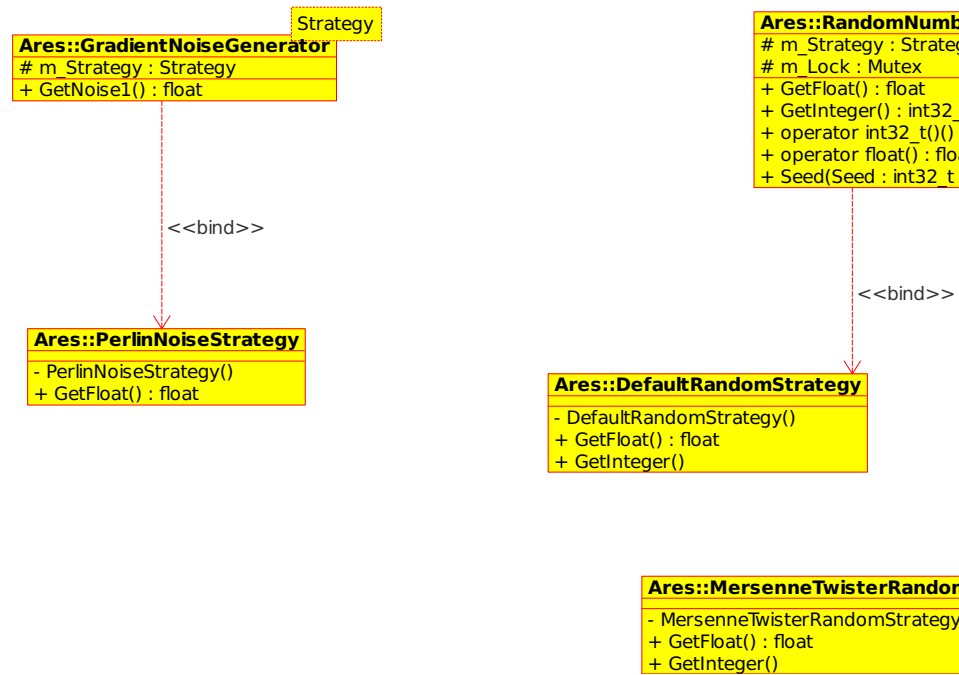


The logging pipeline.

Figure 11.12

11.3.12 Mathematical

Most mathematical routines for matrices and other linear algebra are provided by OGRE 3D. Some things like more advanced random number generation have to be implemented ourselves here.

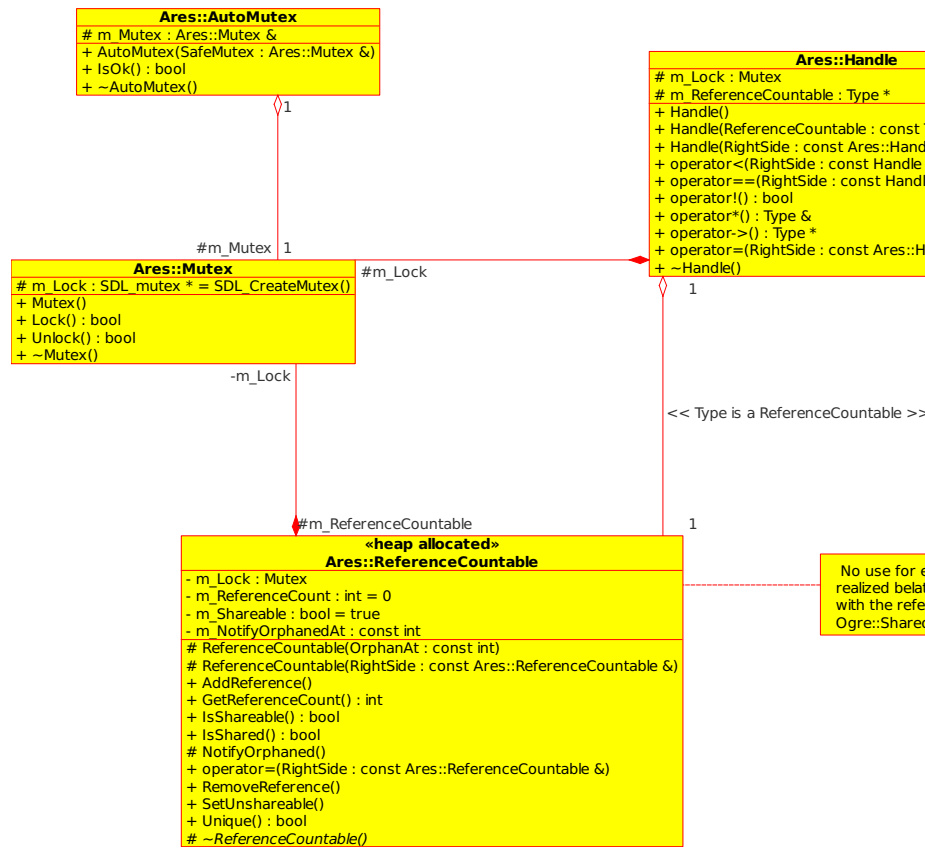


Various mathematical facilities.

Figure 11.13

11.3.13 Miscellaneous

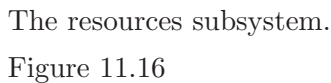
This is a catch-all for classes and functions that had no business elsewhere.



Miscellaneous engine components.

Figure 11.14

The *ResourceManager* is responsible for ensuring that whenever code needs a piece of game data, such as a model or animation, all of its requisites are loaded, in the correct order, only once, and take up only as much room as they absolutely must. The *ResourceManager* and the *FileManager* communicate to help the former locate what it needs physically on disk.



The *ScriptManager* is responsible for exposing all useful aspects of the game engine to the game scripters. Since the engine itself is defined in code, the role of defining what makes Avaneya, Avaneya, is left to script writers.

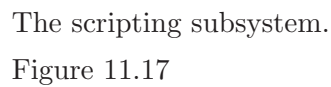


Figure 11.17

12 The Project Crew

12.1 If You Are New

If you are new to the Avaneya crew, welcome! You will probably enjoy working on the project and the sense of community *software libre* projects tend to create. To get you started, here are a couple things you should probably do as soon as you can.

1. Read this handbook, which you are already doing.
2. Get on the low volume announcement mailing list. See [Section 12.5.1 \[Mailing Lists\]](#), [page 55](#) for details.
3. Join the Avaneya Crew on Launchpad. Membership requires approval. If you already received an invite, great. Otherwise, feel free to ask us. There is lots of room in the project for more talent. See [Section 12.5.3.1 \[Launchpad Crew\]](#), [page 57](#) for details.
4. Also join the private discussion mailing list at the aforementioned link. Once on, I recommend you email the list and let everyone know a bit about yourself. They are all good people and will be happy to see a new face. You will be joining fellow musicians, engineers, and artists. See [Section 12.5.1 \[Mailing Lists\]](#), [page 55](#) for details.

12.2 Specialities

Avaneya is a fairly large, creative, and collaborative project, calling upon a variety of different disciplines. These are the different capacities Avaneya contributors fall into. There is no reason why someone who wishes to work in more than one capacity cannot. Many do so already.

2D Artist 2D artists work on the graphical user interface managed by cegui, texturing for models, and other things of that sort. Their areas of expertise range from conceptual art, storyboarding, font design, bump maps, and procedural textures (materials). They can work with a range of software from FontForge to GIMP.

Audio Engineer

These folks creatively can take unassuming sounds and transform them into things usable for science fiction game. An example would be sampling the squeak of a chair or a car driving by with a high end portable recorder and remixing it into the sound of a nuclear electric ion-drive propulsion system. You might find them working with software like Ardour, Rosegarden, and portable high resolution audio recorders.

Cinematic Artist

Cinematics play an important role in games. They prepare the user and set the stage in ways that would be difficult to do during normal game play. They work with tools like Blender, Cinelerra, and Lombard.

- Engineer* The engineers design, discuss, and implement the engine specification, along with writing the Lua script that drive the engine. They work mostly in the languages of C++ and GLSL. The GNU Autotools is useful in the way construction scaffolding is, and they depend on it to ensure the software stays as versatile as possible. There may be some opportunities for assembly level optimizations, but they largely work at a higher level of abstraction that the OGRE 3D rendering engine expects. They coordinate their work with the rest of the team via Bazaar and take care of distribution of pre-compiled binaries via packaging (e.g. debs).
- Modeller* Modellers produce the 3D game models the user sees during game play. They also work with the 2D artists to ensure models are properly textured. They work with Blender, Wings 3D, or any other modelling program that supports standard patent free model formats.
- Musician* The musicians create either new or provide existing tracks for the game. The music falls into two categories. The first is in game ambient music that the user passively listens to. The second is music that is more actively listened to during navigation menus, cinematics, and possibly the separately to be released game soundtrack.
- Researcher* These people provide the background information and attention to detail that makes the game rich. They have an interest in *areology* (the study of Mars), terraforming, simulation and complex modelling, social and political issues (e.g. the *Genuine Progress Indicator*), and whatever else that might be useful.
- Scripter* Scripters write code in Lua that drives and breathes life into the game engine. They will probably work with the engineers to ensure the functionality they require of the AresEngine is exposed safely.
- System Administrator* System administrators run and administer the user forum, moderate the IRC chatroom, monitor the bug tracker on Launchpad, and so on.
- Translator* Translators are what makes Avaneya available to people of different languages. They ensure cinematic subtitles and the game's GUI, and website, are properly internationalized. They work with any tools that support standard GNU gettext and language catalogues.
- Voice Actor* Cinematics and in game audio often requires real people to play a role.

Web Developer

Web developers are familiar with standards and work with things like CSS, XHTML, php, MySQL, and so on. They probably will end up coordinating with the system administrators.

Writer

Writers work closely with the researchers and other artists to provide dialogue and scripts for storyboarding and other game media.

12.3 Avaneya Code of Conduct

Version 1.0

Copyright © 2011 Kshatra Corp.

This Code of Conduct covers our behaviour as members of the Avaneya Community, in any forum, mailing list, wiki, web site, IRC channel, install-fest, public meeting or private correspondence. Avaneya governance bodies are ultimately accountable to the project lead and will arbitrate in any dispute over the conduct of a member of the community.

- **Be transparent, but don't be reckless.** This is a free software project and so we must work as transparently as possible. Having said that, no one likes to have the ending of a good film revealed to them before they have had a chance to see it for themselves. Don't reveal any elements of the storyline or game until it has been discussed and you have been given permission to do so. The crew mailing list is not open to the public and is reserved for Avaneya crew only. Topics range from game storyline spoilers, unreleased conceptual art, security vulnerabilities, and so on. What goes on in this list stays in this list.
- **Be considerate.** Our work will be used by other people, and we in turn will depend on the work of others. Any decision we take will affect users and colleagues, and we should take those consequences into account when making decisions. Avaneya may one day have millions of users and thousands of contributors. Even if it's not obvious at the time, our contributions to Avaneya will impact the work of others. For example, changes to code, infrastructure, policy, documentation, and translations during a release may negatively impact others' work.
- **Be respectful.** The Avaneya community and its members treat one another with respect. Everyone can make a valuable contribution to Avaneya. We may not always agree, but disagreement is no excuse for poor behaviour and poor manners. We might all experience some frustration now and then, but we cannot allow that frustration to turn into a personal attack. It's important to remember that a community where people feel uncomfortable or threatened is not a productive one. We expect members of the Avaneya community to be respectful when dealing with other contributors as well as with people outside the Avaneya project and with users of Avaneya.
- **Be collaborative.** Collaboration is central to Avaneya and to the larger free software community. This collaboration involves individuals working with others in teams within Avaneya, teams working with each other within Avaneya, and individuals and teams within Avaneya working with other projects outside. This collaboration reduces redundancy, and improves the quality of our work. Internally and externally, we should always be open to collaboration. Wherever possible, we should work closely with dependent upstream projects and others in the free software community to coordinate our technical, advocacy, documentation, and other work. Our work should be done as transparently as possible, without ruining the elements of storytelling, and we should involve as many interested parties as early as possible. If we decide to take a different

approach than others, we will let them know early, document our work and inform others regularly of our progress.

- **When we disagree, we consult others.** Disagreements, both social and technical, happen all the time and the Avaneya community is no exception. It is important that we resolve disagreements and differing views constructively and with the help of the community and community processes when necessary.
- **When we are unsure, we ask for help.** Nobody knows everything, and nobody is expected to be perfect in the Avaneya community. Asking questions avoids many problems down the road, and so questions are encouraged. Those who are asked questions should be responsive and helpful. However, when asking a question, care must be taken to do so in an appropriate forum.
- **Step down considerably.** Members of every project come and go and Avaneya is no different. When somebody leaves or disengages from the project, in whole or in part, we ask that they do so in a way that minimises disruption to the project. This means they should tell people they are leaving and take the proper steps to ensure that others can pick up where they left off.

The Avaneya Code of Conduct is an adaptation of the Ubuntu Project's Code of Conduct, also licensed under the [Creative Commons Attribution-Share Alike 3.0](#) licence. You may re-use it for your own project, and modify it as you wish, just please allow others to use your modifications. Remember to give credit to the Ubuntu Project.

12.4 Current Members

12.5 Communication and Coordination

The team uses two primary means of intercommunicating. The first is through the crew mailing list, and the second is over IRC. The Code of Conduct applies to both. See [Section 12.4 \[Code of Conduct\]](#), page 55.

12.5.1 Mailing Lists

Mailing lists have been around for literally decades. They lack the cosmetics and ease of use of a forum, but until our website is ready, it will suffice for the time being.

Avaneya has three mailing lists. The first is a unidirectional announcement mailing list. It is low volume and only intended to communicate from the project to the general public about major project press releases. Anyone can subscribe to it.

Subscribe:

<https://www.avaneya.com/lists/?p=subscribe&id=1>

Browse the archives:

<https://www.avaneya.com/news/announcements/>

The second avaneya@lists.avaneya.com is for anyone to discuss anything related to the project. It is open to everyone.

Subscribe:

<http://lists.avaneya.com/listinfo.cgi/avaneya-avaneya.com>

Browse the archives:

<http://lists.avaneya.com/pipermail/avaneya-avaneya.com/>

The third avaneya-private@lists.avaneya.com is open only to project crew. Topics range from game storyline spoilers, unreleased conceptual art, security vulnerabilities, and so on. If you are a volunteer, you should have been sent a subscription invitation.

Subscribe:

<http://lists.avaneya.com/listinfo.cgi/avaneya-private-avaneya.com>

Browse the archives:

<http://lists.avaneya.com/private.cgi/avaneya-private-avaneya.com/>

When using either of the latter two mailing lists, you may find the following tips useful.

- Do not ever send HTML email. Some peoples' mail clients cannot render it. And even if they can, there is no guarantee it will come out the same. People with visual disabilities may not have their speech synthesizers work properly, since HTML email is much harder to parse. Others may have to pay for additional bandwidth to retrieve your email, since HTML email is larger in size than plain text.¹
- When you reply to a post, remember to reply to the list and not just the original sender privately. Unless you had intended to, the mailing list is setup so that everyone who subscribes to it may benefit from productive communication on it. Sometimes this may not happen until years later when a new subscriber searches through old archives to find a solution to a problem they were having that was solved long ago.
- When replying to a post, if you have your subscription configured to use batch digest mode,² you do not need to copy the whole digest. Just quote the minimum needed for context.
- Check the subject heading of your reply to a message posted on the list to make sure it still reflects the original post. Some mail readers, if you have batch digest mode enabled in your subscription, will change the heading to reflect the batch digest's subject heading, instead of the specific message within it you are replying to.

¹ For more information, consider reading <http://www1.american.edu/cas/econ/htmlmail.htm>

² When batch digest mode is enabled, the server will "batch" together emails into groups and then send it to you as a single compilation to cut down on the amount of email you receive.

- When you reply, remember to reply at the bottom and not at the top of the message. Top posting is generally not encouraged because it makes preservation of chronological order difficult to follow for readers.³

12.5.2 Internet Relay Chat (IRC)

IRC is among the oldest forms of realtime chat over the internet. Avaneya has a channel (**#avaneya**) on the Freenode server (**irc.freenode.net**). You can use whatever client you like, but it is recommended you use one that supports SSL.

Make sure you register your chosen nick name with the *nickserv* on Freenode. This ensures you are consistently identifiable to others in the chat room.

Whenever you would like to send someone a message publicly in the channel, you should precede your message with their nick name. This is because many people have their IRC clients configured to alert them audibly when that happens, as opposed to every time anyone says anything in the channel. Usually you only need to type the first few letters of their nick name and hit tab to have your client complete it.

12.5.3 Launchpad

Launchpad is a project started by Canonical, the company behind the Ubuntu project. It is an online service that allows for coordinated software project collaboration. It provides services for source control management, blueprints, support, bug tracking, and more. The Avaneya project, the people behind it, and the source code as it develops can be found there.

If you are a contributor, make sure you remember to add yourself to the Launchpad project crew.

Launchpad project website:

<https://launchpad.net/avaneya>

Launchpad crew website:

<https://launchpad.net/~avaneya>

12.5.3.1 Bug Tracker

Launchpad's bug tracker tracks all issues submitted to it originating both from users and the crew.

Bug tracker:

<https://bugs.launchpad.net/avaneya>

12.5.3.2 Bazaar Revision Control

We use Bazaar for revision control, hosted on Launchpad. You can browse it on the web here:

³ This explains why top posting is a bad idea: https://secure.wikimedia.org/wikipedia/en/wiki/Top_posting#Top-posting.

<https://code.launchpad.net/~kip/avaneya/trunk>

Some ask why we had not initially chosen a distributed revision control system (DRCS), one class of source control management systems (SCM). SCMs are used to allow multiple people to collaborate over a shared set of files, track revisions and logs, and a number of other things. There are many free programs that allow this, but they can generally be grouped into two categories or paradigms based on how they are expected to be used.

DRCS are akin to peer-to-peer software where they can be used in the absence of a central canonical server. Proponents argue users are better able to work productively when not connected to a network, most operations are much faster since no network is involved, and more. Probably the strongest point raised is it allows participation in projects without requiring permissions from project authorities, and thus arguably better fosters a culture of meritocracy instead of requiring "committer" status. Software that implements these include Mercurial, Git, Bazaar, Monotone, Darcs, and others. This approach has been popularized by the open source movement in recent years, as it captures the "bazaar" approach to software development (think of the Persian marketplace).

CRCS, centralized revision control systems, are akin to peer-to-server model. They have a single canonical repository on a single server. Proponents argue it is more straightforward to contribute to, work is better coordinated, has a more approachable learning curve, backups are more straightforward, and has been around longer. CVS, Subversion, and many others implement this approach. This approach has been popularized by the free software movement, as it captures the "cathedral" approach to software development (think of a central coordinator).

Many people had suggested we use Bazaar because it has a feature that Subversion, what many are use to, does not, DRCS. It is clear that it is perfectly capable of the distributed approach, but that should not be characterized as a feature any more than the specific colour of a car is a feature. It is not a feature, but a preference. Nevertheless, we ended up settling with Bazaar because it can function in the DRCS approach, is the only SCM supported by Launchpad, integrates well with modern graphical GNU desktop environments,⁴ and improves on the features Subversion supports. Besides, it was time to try something new and learning something new is usually not a bad idea.

12.5.3.3 Blueprints

Launchpad provides a feature called Blueprints which allows you to track the design process from basic feature specifications all the way to implementation. Our project's currently available blueprints include:

- **ares-architectural-design:** This document describes the AresEngine's internal architectural design. See the README for details.

<https://blueprints.launchpad.net/avaneya/+spec/ares-architectural-design>

- **ares-package-design:** The AresPackage manifest file format and documentation is provided. See [Section 11.1 \[AresPackages\]](#), [page 23](#) for details.

⁴ As an example, check to see if your distribution carries the *nautilus-bzr* package.

<https://blueprints.launchpad.net/avaneya/+spec/ares-package-design>

- **ares-events-design:** The event type schema and definitions for built-in event types, Events.xsd and Events.xml respectively. See [Section 11.3.7 \[Events\]](#), [page 39](#) for details.

13 Licensing Rationale

Avaneya is composed of different types of files that fall into general categories. The game is licensed under multiple licenses, with a given license for each category. These categories are for *artwork*, *code*, *documentation*, and *music*.

- **Artwork:** This includes all literary works, cinematics, models, audio and voice effects, textures, materials, concept art, fonts, screenshots, and other relevant non-executable creative data.

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The license ensures that, under the default conditions, unless given permission, others cannot use it for commercial purposes (NC), must give attribution (BY), and if they alter, transform, or build upon it, they must distribute the resulting work only under the same or similar license to this one (SA). Everyone is free to copy, distribute, and transmit the work, as well as to adapt the work as they like. These are just the default conditions and can be waived with the permission of the copyright holder.

- **Code:** This includes the AresEngine, shaders, Lua scripts, build environment scripts, and any other relevant executable data.

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In a nutshell, this license ensures that users have four fundamental freedoms that are always protected. These are the freedom to use the software for any purpose, the freedom to change the software to suit your needs, the freedom to share the software with your friends and neighbors, and the freedom to share the changes you make. The license for most software and other practical works are designed to take away your freedom to share and change the works. By contrast, the GNU General Public License is intended to guarantee your freedom to share and change all versions of a program - to make sure it remains free software for all its users.

- **Documentation:** This includes UML schematics and other design documents, doxygen output, man and info pages, this handbook, and other relevant data.

These objects are licensed under the terms of the GNU Free Documentation License 1.3, copyright © 2010, 2011 Kshatra Corp. See [Section B.2 \[License GFDL\]](#), [page 75](#) for the full text of the license.

The Free Software Foundation explains the purpose of the license as being to make a manual, textbook, or other functional and useful document "free" in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or noncommercially. Secondarily, this license preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

- **Music:** This includes all music in Ogg Vorbis, FLAC, Speex, or other formats and associated project files.

These objects are licensed under the terms of their respective artists or publishers. We feel that music does not have to be free, but it is preferred that it be at least shareable. This is the position of Richard Stallman of the Free Software Foundation, along with many artists.

Appendix A Glossary

The following is a collection of terms used in the game world that range from the everyday colloquial to technical terminology. Familiarizing yourself with them will be useful in ensuring the game remains as rich as possible.

Albedo: The proportion of incoming light reflected. It is the ratio of reflected light to total incident light. That is, a material with an albedo of 1 is a perfect mirror whereas a material with an albedo of 0 absorbs all incident light.

Endothermic reaction: A chemical reaction that requires energy to be put into it in order to react. An example would be cooking an egg. The egg doesn't change unless you apply heat to it. This is contrasted with an *exothermic reaction*.

Exothermic reaction: A chemical reaction that releases energy as part of its reaction. An example would be burning wood. As the wood changes, it releases energy in the form of mostly heat.

Genuine Progress Indicator: The GPI is a system of true cost accounting which is intended to be a replacement to the GDP, gross domestic product, sometimes called the gross national product, GNP. The GPI works by taking into account all costs of an activity to society and provides a net balance sheet. The latter, on the other hand, only functions as an income sheet by tabulating the total amount of goods and services produced in a year.

An example where the difference between the two is well illustrated is with the tobacco industry. The GDP would account for the value of all cigarettes sold (a positive figure). Conversely, the GPI would also account for the total value of all units sold, but then go on to subtract the deficits socialized to everyone in the form of health costs, fires, garbage collection, environmental toxicity, and the deaths of approximately 5,000,000¹ people every year (a negative figure).

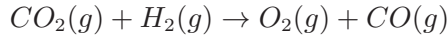
Regolith: What most refer to as dirt. More technically, it is the the loose heterogeneous mixture of material that blankets the solid rock.

Rhodium: An elemental chemical with the symbol Rh and atomic number 45. It is a member of the platinum family and considered to be the most precious metal of that family, even exceeding the value of gold. It is also one of rarist.

Usually the only way of getting any kind of high quantity mineral is through high-grade ore. This only happens when complex hydrological and volcanic processes have happened, which in our solar system, has only occurred on Mars and Earth - hence why the Moon is barren. But unlike the Earth, Martian deposits have remained untapped.

¹ *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*, Naomi Oreskes, Bloomsbury Press, 2010

RWGS reactor: The reverse-water-gas-shift reactor is a method of producing oxygen (O_2) from carbon dioxide (CO_2). This is useful because the latter is plentiful in the Martian atmosphere at 95 %.



The process has been known since the mid 1800s and works by reacting carbon dioxide and hydrogen gasses together over a copper-on-alumina catalyst. Aqua (liquid water) and carbon monoxide gas are produced as byproducts. The aqua is split via electrolysis to produce hydrogen and oxygen gasses. The hydrogen can then be recycled back into the reactor and the carbon monoxide purged out into the atmosphere.

The reactor needs to be at 400 °C and at low pressure. It requires about 180 watts of power, or about 3 m^2 of solar panels on a fully sunny day's average solar flux. At that energy rate, you can expect to produce about 1 kg per day of oxygen, which is sufficient for a single person. The reactor requires power because it is an *endothermic reaction*. However, it is possible to use a *Sebatier reactor* in tandem, which is an exothermic process, to provide the heat required to drive the RWGS reaction.

To start the process, only a small amount of water is required which acts as a reagent. By importing hydrogen from Earth, it acts to the colonists' advantage in allowing it to be leveraged in the creation of water, or hydrogen gas if needed.

Sebatier reactor: A chemical process for creating methane CH_4 from CO_2 and hydrogen. This is useful because carbon dioxide gas is plentiful in the Martian atmosphere at 95 %.



The reactor needs to be at 400 °C and at low pressure. This makes it almost the same as the *RWGS reactor* except that it uses a different catalyst to make methane instead of carbon monoxide. You can either use nickel, which is cheap, or ruthenium-on-alumina, which is safer, but more expensive.

Sol: Short for solar day, the length of time a planet takes to rotate completely on its polar axis with respect to the sun. Terrans call this a day, Martians a sol. See also *yestersol*.

Yestersol: The sol preceding the current one. This is the Mars analogue to the Terran yesterday, but different since the length of a sol on both worlds is different.

Appendix B Licenses

B.1 GNU General Public License

Version 3, 29 June 2007

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Preamble

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