1 Construction Basics

1.1 Resources

Currently, EL uses four resources for its production chain (though the recipe system allows for much more complicated systems).

MetalOre Assumed to be iron ore (but not explicitly stated as such) but with a very slightly higher density ($5.5t/m^3$ vs $4.5 - 5.3t/m^3$).

Metal Assumed to be iron (but not explicitly stated as such) and thus has a density of $7.8t/m^3$.

RocketParts Assumed to be sub-parts ready for assembly into actual parts, and thus has a very low density of $0.5t/m^3$.

ScrapMetal The true product of any machine shop: all machine shops produce scrap metal in various forms and efficiencies. The lumps of metal handed over to the customer are really the left-overs from producing scrap metal. Scrap metal generally does not pack well, though better than parts, so a density of $0.8t/m^3$ was chosen as an average.

1.1.1 Prospecting and Mining: dirt? to MetalOre

In order to obtain MetalOre when away from KSC, one of the augers is used to mine MetalOre from the surface of the planet or moon. EL uses the stock resource distribution system configured to distribute MetalOre, so prospecting is done as for stock's Ore resource, but with a focus on MetalOre instead.

Kethane and Karbonite Prior to KSP 1.0, EL relied solely on Kethane for its prospecting and mining, and there was an adaptation to make EL use Karbonite instead. As of KSP 1.0 (EL 5.1.90) Kethane is completely optional, but if present, will be used on top of the stock resource system. Scanning is quite separate, but mining is done using the exact same augers. Mining outside a MetalOre deposit created by Kethane will extract MetalOre at the rate dictated by the concentration given by the stock system (1% to 15%), but deposits created by Kethane effectively provide hot-spots of 100% concentration.

The Karbonite adaptation seems to have been mothballed, but it was mostly a parts mod with configs for EL, so it may still be usable.

It may be worthwhile thinking of the stock system providing a means to extract MetalOre from a larger mix of "dirt", while the Kethane system provides access to rich veins of MetalOre.

1.1.2 Smelting: MetalOre to Metal

MetalOre is converted to Metal via smelting. Smelting is the process of reducing[1] metal oxides. EL assumes MetalOre is Fe_2O_3 (the most common iron ore on Earth). Reducing Fe_2O_3 is a three-step process (from Wikipedia):

[1] chemistry term, the opposite of oxidizing (or reduction vs oxidization)

Stage One $3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$

Stage Two $Fe_3O_4 + CO \rightarrow 3FeO + CO_2$

Stage Three $FeO + CO \rightarrow Fe + CO_2$

However, this really happens all at once in a smelter so the effective process is $3Fe_2O_3 + 9CO \rightarrow 6Fe + 9CO_2$.

Fe has a molar mass of $55.845g/mol$, O has a molar mass of $15.999g/mol$ [2], so $479.061g$ of $3Fe_2O_3$ will produce $335.070g$ of Fe. This leads to a MetalOre to Metal mass conversion rate of 0.699431 (0.493188 volume (resource unit) conversion rate).

1.1.3 Working: Metal to RocketParts

Metal is converted to RocketParts by working it. Currently, this is done using either the workshop (big blue part in Utilities), or the workbench (tower with little platforms in Pods). Unfortunately, the process is quite bogus: Metal is used for for everything, and the conversion speed is far too fast. However, the efficiency (0.7 by mass) is reasonable: it is the estimated average of various means of production: cutting cast iron parts leads to high efficiency, but cutting lumps of steel can lead to fairly low efficiency depending on just how much metal needs to be cut away. At the same time, ScrapMetal is produced at a rate of 0.2995 by mass (some scraps are lost).

1.1.4 Remelting: ScrapMetal to Metal

ScrapMetal can optionally be remelted to Metal using a smelter. The process is lossless (conversion rate of 1), the loss (very small) occurs when producing the ScrapMetal. Storing and reclaiming ScrapMetal is fully optional: running out of storage will not stop Metal to RocketParts conversion.

1.1.5 Building: RocketParts to Rockets

Building is done by the launchpads, orbital dock, or survey station (or just "pads" for short). The rate is governed by the overall vessel productivity (measured in kerbal-hours (Khr)) shared amongst active pads. Each ton of rocket (dry-mass) requires five kerbal-hours (ie, 5Kh/t).

1.2 Productivity

All kerbals have a base productivity score computed from their stupidity, courage, and bad-ass characteristics. The more stupid a kerbal is, the less that kerbal will contribute to the workshop's (and thus the overall vessel's) productivity,

[2] EL currently does not model CO consumption or CO_2 production, but C has a molar mass of $12.0107g/mol$ giving CO a molar mass of $28.0097g/mol$ and CO_2 a molar mass of $44.0087g/mol$

and more courageous kerbals will, in general, contribute less than less courageous kerbals, though bad-ass kerbals complicate the relationship. It is entirely possible for a kerbal to have negative productivity.

If the KerbalStats[3] mod is installed, then the amount of time a kerbal has spent in certain workshops (currently only EL's blue workshop (afaik)) improves the kerbal's productivity.

A workshop's productivity is the sum of the productivities of all kerbals working in that shop. A vessel's productivity is the sum of the productivities of all workshops in that vessel. If the vessel's productivity is greater than zero, then construction will progress. Negative productivity does not cause production to become destruction, instead it causes a productivity deficit that must be overcome by better construction kerbals.

1.3 Construction Skill

Kerbals with the construction skill (by default, engineers) are the cornerstone of workshop productivity. However, their space-faring (stock) experience affects their productivity greatly.

0 stars The kerbal can work in a fully equipped workshop.

1 star The kerbal can work in any workshop.

2 stars The kerbal is always productive in a fully equipped workshop (base productivity still matters, but to get negative productivity, the kerbal would have to have infinitely negative base productivity).

3 stars The kerbal is always productive in any workshop.

4 stars The kerbal enables skilled workers in any workshop (a 4-star construction kerbal in an under-equipped workshop allows 0-star construction kerbals to contribute).

5 stars The kerbal enables unskilled workers in a fully equipped workshop (a 5-star construction kerbal in a fully equipped workshop allows any kerbal, even those without the construction skill, to contribute).

1.3.1 Unskilled kerbals

Unskilled kerbals cannot work unless a 5-star construction kerbal is present in the same workshop, and the workshop must be fully equipped, but if the kerbal's experience level is 2 or less, and the kerbal's base productivity is negative, the kerbal will detract from the workshop's productivity.

[3] KerbalStats: http://forum.kerbalspaceprogram.com/index.php?/topic/89285-105-kerbalstats-v201/

1.3.2 Non-career modes

In sandbox (and science?) mode, all kerbals are level 5, so there will be no negative contributions, and if there is at least one construction kerbal in the workshop, then all kerbals of sufficient ability will contribute.

1.4 Workshops

Workshops, too, affect productivity. All workshops have a productivity factor that is multiplied by the sum of the productivities of the kerbals working in that shop. The resulting productivity is then passed to the vessel.

1.4.1 Fully equipped

Fully equipped workshops are those with a productivity factor of 1.0 or more, or specially marked workshops with lower productivity factors. EL's blue workshop, and the rocket workbench are both fully equipped workshops.

For role-play purposes, "fully equipped" can be thought of as the workshop having all the necessary tools, and the productivity factor as being the quality of the tools or the level of automation available.

1.4.2 Other parts

All stock crewed parts act as under-equipped workshops. In addition, all crewed command pods, including those from other mods, act as under-equipped workshops. Many base-building mods (eg, USI-MKS, Pathfinder) provide workshops (refer to those mods for details).

1.5 Pads

All construction is done at "pads", whether the pad is an orbital dock, a launchpad, or a survey site (marked out using survey stakes and managed by a survey station).

Initiating construction is the same for everything: open the build window (via either the toolbar button (blizzy's toolbar), or the Show UI button in the PAW[4]), select the craft to build, and press the Build button. Between selecting the craft to build and pressing the Build button, the required and optional resources for the build will be displayed in a preview. There is no need to have all the required resources on-hand when beginning the build: if they run out during the build, the build will stop until the resources become available and then automatically resume. The resources can become available via supply runs or local processing.

1.5.1 Launchpads and Orbital Docks

Technically, there is no difference between a launchpad and an orbital dock: they operate exactly the same way. The difference comes in the physical attributes of the parts: launchpads are optimized for grounded operation, and the orbital dock is optimized for orbital operation.

[4] Part Action Window (right-click menu)

Adjusting the optional resources in the preview will set the defaults for the amounts to be transfered upon release.

1.5.2 Survey Stations and Survey Stakes

Survey stations use local survey sites to specify the location and orientation of the built vessel. Survey sites are sets of one or more survey stakes with the same name and within range (200m) of each other.

Adjusting the optional resources in the preview will have no effect as no resources will be transfered.

A stake's name defaults to the name of the kerbal who planted it with "Base" appended. Thus if Valentina plants a stake, it will be named Valentina Kerman Base. Thus, when creating a site consisting of more than one stake, it is easiest to have only one kerbal do the stake planting. Also, if multiple local sites are desired, getting a different kerbal to plant the stakes for each site will make it easier.

2 Survey System

EL's survey system greatly eases the seeding (or even complete build-out) of bases, and works equally well for building ships and other vessels. However, they do have one disadvantage: any optional resources (liquid fuel, oxidizer, electric charge, etc) will *not* be transfered: the build will be empty of such resources (freedom is not free), but as KIS[5] is required to place the stakes, and KAS[6] is almost always installed with it, this disadvantage should be only minor[7].

The survey system consists of two parts[8]: the survey station, and the survey site. The survey station (a re-purposed hitchhiker can) is used to keep track of the survey sites and do the actual building (it serves the same purpose as the orbital dock or a launchpad, but must be landed), and must be flown down to the surface in the vicinity of where the builds will occur. The survey site is ephemeral: it is marked out by one or more survey stakes and is used to specify the location and orientation of the build.

Stakes have two modes with seven settings in each mode (default is Direction:Origin):

Direction these are used to control the orientation of the build.

- **Origin** used to mark the location above which the build's root part will be placed, and also forms the reference point for other direction stakes that aren't in pairs.
- **-X and +X** used to specify the lateral (port (-X) and starboard (+X)) axis of the build (both VAB and SPH). If both -X and +X are used, then the origin is is ignored, otherwise the axis runs from -X to origin or origin to +X.

[5] Kerbal Inventory System: `http://forum.kerbalspaceprogram.com/index.php?/topic/101928-105-kerbal-inventory-system-kis-126/`

[6] Kerbal Attachment System: `http://forum.kerbalspaceprogram.com/index.php?/topic/83468-105-kerbal-attachment-system-kas-055/`

[7] It can, however, lead to good entertainment: https://www.youtube.com/watch?v=67vth86RQH0&t=1525

[8] If you're thinking KSP parts, then it's three: survey station, survey stake, and mallet.

-Y and +Y used to specify the "vertical" axis of the build (relative to the floor in the VAB or SPH). If both -Y and +Y are used, then the origin is is ignored, otherwise the axis runs from -Y to origin or origin to +Y. NOTE: not recommended, very advanced usage.

-Z and +Z used to specify the ventral (VAB) or fore/aft (SPH) axis of the build. If both -Z and +Z are used, then the origin is is ignored, otherwise the axis runs from -Z to origin or origin to +Z.

* If none of the axis direction stakes are used, then the default orientation is such that the build's +Y axis is the local up, +X axis points east, and +Z points south (same as on the KSC launchpad).

* If the axes marked out by the stakes are not perfectly orthogonal, then the build will be oriented such that the errors are balanced.

Bounds these are used to control the placement of the build based on its bounding box rather than its root part.

Origin used to mark the location of the root part along any axis that has not been bound.

-X and +X used to mark the lateral (port (-X) and starboard (+X)) edges of the build. If only one of -X or +X is used, then that edge of the build will be exactly on that stake, otherwise the the X-axis center of the build's bounding box will be centered on the midpoint between the two stakes.

-Y and +Y used to mark the "vertical" edges of the build. If only one of -Y or +Y is used, then that edge of the build will be exactly on that stake, otherwise the the Y-axis center of the build's bounding box will be centered on the midpoint between the two stakes. NOTE: use of the +Y bounds stake is not recommended unless you know what you are doing.

-Z and +Z used to mark the ventral (VAB) or fore/aft (SPH) edges of the build. If only one of -Z or +Z is used, then that edge of the build will be exactly on that stake, otherwise the the Z-axis center of the build's bounding box will be centered on the midpoint between the two stakes.

* Bounds stakes and direction stakes work together: any unbound axis of the build slides along that axis of the reference frame created by the direction stakes (or the default frame if no direction stakes are used).

* There is actually only one origin stake: there is no difference between a bounds origin stake and a direction origin stake. The appearance of there being two origin stakes is due to the overly simple controls.

* If multiple stakes of the same type+setting have been placed, then they will be averaged together to form a virtual stake of the same type+setting. This can be very useful with multiple origin stakes to avoid the build

clipping into the stake when the lowest part of the build is directly below the root part.

* If no origin stakes have been placed, then the average of all other stakes is used as the origin point.

* The actual location of the stakes is about 19cm above the ground.

* If no Y bounds stake has been placed, then the origin acts as an implicit -Y bounds stake (otherwise almost all builds would spawn in the ground).

2.1 stuff

Ok, about the surveyed builds...

Firstly, they are still a work in progress: they are working as intended and most of the planned features seem to be working, but two important features are not yet implemented and there may be more bugs lurking in the code (over 800 lines).

Secondly, surveyed builds flat out require Kerbal Attachment System: the survey stakes cannot be attached to any part via any means (node attach, surface attach, KAS attach). They can, however, be attached to planetary surfaces, carried around by kerbals (<2kg), and put in KAS storage containers. Stakes are used to determine the placement of the build craft: both location and optionally orientation.

Thirdly, to make use of the survey stakes, your build vessel needs to have a survey station. Currently this is a clone (via MM magic) of the stock hitchhiker can. I will create a new part for this once I've had a break and will ensure it is physically compatible, but I suggest avoiding surface attachments as the exact shape may differ, or parts may be animated. Use of the survey station is exactly the same as a pad, except it must be landed for it to work.

Finally, craft built via a survey station will not be loaded with any resources. Probes with neither ox-stat solar panels nor RTGs (or similar mod parts) will be DOA. Resources can be transfered by connective via either docking or KAS.

And now a little bit about actually using the stakes...

- Stakes have "usage modes". These can be seen via the right-click menu from EVA. The possible settings are: Origin, +X, +Y, +Z, -X, -Y, -Z.

- Stakes can be renamed via Rename Stake in the right-click menu. The dialog is the same as for Rename Vessel, but the ship type has no meaning. The name defaults to "<kerbal name> Base". Stakes of the same name will be considered to be part of the same survey site. Multiple survey sites is one of the not-yet fully implemented features. Multiple sites within range of the survey station may result in interesting outcomes.

- Stakes in Origin mode determine where the built craft will be placed (the root part). If the site has multiple Origin stakes, then their positions will be averaged. This is a very useful feature :).

- Stakes in +/- XYZ mode determine the orientation of the built craft. The default is for the starboard size of the craft to face east (same as a normal launch). +X is starboard, -X is port. I have not done sufficient testing, but +Z is forwards for craft built in the SPH (this I have tested).
- Multiple stakes with the same orientation mode in the one site are averaged.
- Mixing orientation modes in a site may result in interesting outcomes.
- Moving stakes around does not reset their modes. Putting them away in a KAS container probably does (not tested, but I doubt KAS preserves the information).
- Launch clamps work well enough with surveyed builds, but the spawned craft has its bottom about 20cm above the ground (for default orientation). Results may vary on uneven ground.

Essentially, surveyed builds make it a little easier to get bases going as you don't need to fly in an awkward launchpad.

2.2 Direction Stakes

Nice to see that NASA uses a right-handed system (I hate unity's left-handed system). Unfortunately, I have to stick with the LHS for my description or I'll confuse myself.

Ok, I have verified that the survey station averages all of a site's stakes to find the center, but if Origin stakes are present, it then sets the center to the average of the Origin stakes (I guess I wasn't feeling that sadistic).

Once the survey station has set the center, it goes on to find the orientation.

- If the Y axis has not been staked out, then it will, without fail, be the local vertical (ie, directly along the radial vector from the center of the celestial body through the center of the site). Local ground slope is ignored. The XZ plane is horizontal.
  - If neither X nor Z has been staked out, then the X axis is set to point east. This will not work at the poles (which way is east? Every direction is either south or north). The Z axis is then set to point south. This is the same orientation for rockets on the pad at KSC.
  - If only X has been staked out, then the X axis is set to point in the same direction, and the Z axis will be at 3 o'clock (if the X axis is 12 o'clock) when viewed from above.
  - If only Z has been staked out, then it is a similar story, but the Z axis is 12 o'clock pointing in the same direction and the X axis is 9 o'clock.

  - If both X and Z have been staked out, then the errors for the X and Z axes will be balanced, though X might be reversed if you get the placement wrong. The Y axis is still vertically up.

- If the Y axis has been staked out, but the X axis has not, then the X axis will be the local vertical. The YZ plane is horizontal.
  - If the Z axis has not been staked out, then it will be pointed at 3 o'clock with the Y axis at 12 o'clock.
  - If the Z axis has been staked out, then the Y and Z axis errors will be balanced.

- If both the Y axis and the X axis have been staked out, but the Z axis has not, then the Z axis will be the local vertical, and the XY plane will be horizontal.
  - The X and Y axis errors will be balanced.

- If all three axes have been staked out, then I hope you know what you are doing. All three axis errors will be balanced. Used carefully, this might be useful on extreme slopes, or maybe in the vicinity of a Mun arch.

Note: it is intended that the vessel is built flat. It is not accidental behavior, and it is why I modified the launch clamps.

2.3 Bounds stakes

Some points about Bounds stakes:

- Bounds stakes use the same highlight colors as Direction stakes, but flash.
- Single (for a specific axis) Bounds stakes will lock the relevant side of the vessel's bounding box to that stake (ie, the box face and the stake will be coplanar).
- Two Bounds stakes (eg, -X and +X) will cause the box to be centered between the stakes.
- No Bounds stakes on an axis will center the vessel's root part on the Origin stake (or the average of all stakes if there is no Origin stake).
- As per Origin and Direction stakes, multiple Bounds stakes of the same axis (eg, -Z) will be averaged together.
- There is no difference between a Bounds Origin stake and a Direction Origin Stake.

Again, I apologize for suggesting the use of bounds stakes when I had not yet released them. I had begun working on them right after releasing 5.0.2, so I had forgotten they were new.

3 Recipes

On 29/03/2016 at 0:25 PM, goldenpsp said:

I would imagine the EPL recycling bin would need some sort of MM config as by default it isn't going to recycle to material kits.

All it needs is appropriate EL_RecycleRecipe(s) and EL_TransferRecipe(s) (both are for resources, not parts). Tank contents use EL_TransferRecipe (to override other recipes, so not always needed), parts get broken down into appropriate resources using their EL_PartRecipe(s), and those resources use EL_RecycleRecipe (any resource with a EL_ResourceRecipe but no EL_TransferRecipe will evaporate from takes, and evaporate when recycling parts if there is no EL_RecyleRecipe for that resource).

When building:

- Any resource mentioned in EL_PartRecipe or EL_ModuleRecipe is required for building (but not for filling tanks).
- Any stored resource that has an EL_ResourceRecipe becomes a required resource (eg, SolidFuel).
- Any resource stored in a part inside a KIS container becomes a required resource, regardless of recipes.

When recycling:

- Done on a part-by-part basis. Some of you may have had spotty results recycling entire vessels: that is intentional, and there is a way around it (see if you can guess).
- Any resources stored in the part are drained. Those with an EL_ResourceRecipe but no EL_TransferRecipe are lost, otherwise they transfer as dictated by the EL_TransferRecipe.
- The part is then broken down into the resources specified by its EL_PartRecipe and EL_ModuleRecipe(s). Those resources with an EL_ResourceRecipe but no EL_RecycleRecipe are lost, otherwise they get broken down further in accordance with their EL_RecycleRecipe.
- Whether tranferring (from a tank) or recycling (the part itself), resources with no recipe are reclaimed as-is at a 1:1 ratio.
- Of course, any reclaimed resource need storage space.

I hope that helps anybody wishing to tweak recipes. There are example recipes in EL's Resources directory, and, I imagine, somewhere in USI's tree. Only EL_PartRecipes need to be MMed (into the part), the rest are independent.

4 Modules provided by EL

4.1 Overview

ExRecycler Destroys anything it touches (including unfortunate kerbals) reclaiming what resources it can.

ExLaunchPad Builds complete vessels attached (pseudo-docked) to the current vessel. Allows post-build resource transfer without any extra fuss. Supports building both landed or in orbit.

ExTarget Allows a part to be targeted. Includes orientation so it works with any docking alignment mod (DPAI, navball, and navhud are known to work).

ExWorkshop Collect productivity from kerbals in the part. Works with either normal parts with crew capacity or command chairs.

ExSurveyStation Builds complete vessels at locations marked out using survey stakes (parts with the ExSurveyStake module). Does not allow post-build resource transfer (freedom is not free), but as KIS[9] is required to place the stakes, and KAS[10] is almost always installed with it, survey stations are probably the preferred tool for landed operations.

ExSurveyStake Marks locations for survey station. In the current implementation, a stake must be the only part in the vessel for the survey station to recognize it.

4.2 Configuration

For the most part, EL places no restrictions on the models used for parts using EL's module, so unless otherwise stated, models are completely free-form as far as EL is concerned.

4.2.1 ExRecycler

Model Requirements The only requirement is the recycle field. The recycle field must be a trigger collider and should (must?) not touch anything else.

Part Requirements None.

[9] Kerbal Inventory System: `http://forum.kerbalspaceprogram.com/index.php?/topic/101928-105-kerbal-inventory-system-kis-126/`

[10] Kerbal Attachment System: `http://forum.kerbalspaceprogram.com/index.php?/topic/83468-105-kerbal-attachment-system-kas-055/`

Module Fields

RecycleField_name Specifies the name of the transform for the recycle field collider. Defaults to "ReycleField".

RecycleRate Specifies the recycling rate in tons/second. Defaults to 1.0t/s.

4.2.2 ExLaunchPad

Model Requirements No requirements, but it is highly recommended that the part has plenty of free space "above" (positive Y-axis in KSP/Unity, Z-axis in Blender) the launch transform.

Part Requirements None.

Module Fields

SpawnHeightOffset Specifies the distance in meters above the launch transform of the lowest point of the spawned vessel. This is most useful when the model does not have a specific spawn transform. Defaults to 0.0m.

SpawnTransform Specifies the model transform to be used as the launch transform. Optional, but using a spawn transform allows finer control over the launch position than that afforded by SpawnHeightOffset, and also allows the orientation to be specified. If not specified, the model's root transform will be used as the launch transform (setting SpawnHeightOffset is highly recommended, but not as highly as having a spawn transform).

PadName Specifies the name of the launchpad. Note that this is editable by the user both in the editor (VAB/SPH) or in flight.

4.2.3 ExTarget

Model Requirements None.

Part Requirements None.

Module Fields

TargetTransform Specifies the model transform to be used as the target. If not specified (the default), the model's root transform will be used.

TargetName String to be added after the host vessel's name when set as target. Defaults to "Target".

4.2.4 ExWorkshop

Model Requirements None.

Part Requirements The part must have some crew capacity. This can be via either the part's crewCapacity field, or KerbalSeat (stock KSP) modules (currently, not both: for KerbalSeat to be checked, the crewCapacity must be 0). Note that parts may have multiple KerbalSeat modules on them (eg, EL's Rocket Workbench).

Module Fields

ProductivityFactor Specifies the multiplier for calculating kerbal productivity. Must be greater than 0. All workshops with ProductivityFactor greater than 1.0 are considered to be fully equipped (ie, even 0-star kerbals with the construction skill can contribute). Defaults to 1.0.

FullyEquipped If true, then even workshops with productivity factors less than 1.0 are considered fully equipped allowing 0-star kerbals to contribute.

IgnoreCrewCapacity If true, the workshop will operate even if the part's crewCapacity is 0 (and not check for KerbalSeat). This is most useful on parts with dynamic crew capacities (eg, inflatables).

4.2.5 ExSurveyStation

Model Requirements None.

Part Requirements No requirements, but as kerbals improve its range, having crew capacity (crewCapacity > 0 or KerbalSeat modules) is recommended.

Module Fields

StationName Specifies the name of the survey station. Note that this is editable by the user both in the editor (VAB/SPH) or in flight.

4.2.6 ExSurveyStake

Model Requirements None except any required by KIS for ground attachment.

Part Requirements As the survey station will not look at vessels with more than one part to check for the ExSurveyStake module, the part should be configured to be ground attached using KIS. However, parts designed to be dropped via staging or decoupling will work, too, so long as the resulting vessel consists of only the one part.

Module Fields None.