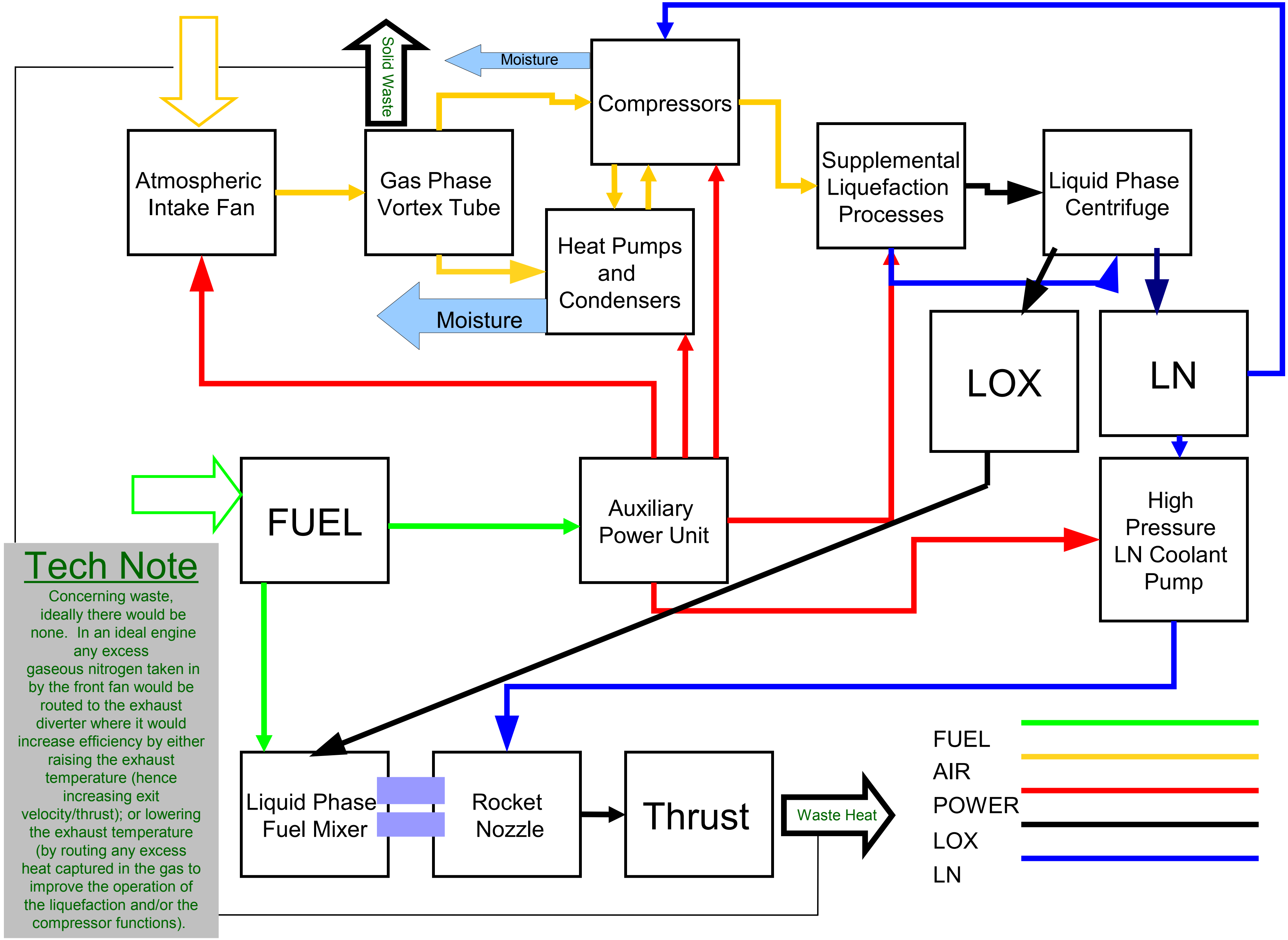
CPPC - Combined Phases Propulsion Concept



Air Fractionation Options

- GAS PAHSE FRACTIONATION – fractionate air as a gas
- LIQUID PHASE FRACTIONATION – fractionate air as a liquid
- COMBINED PHASES FRACTIONATION – fractionate as gas, then as liquid

Pre-liquefaction

Gas Phase

1) Vortex Tube
2) Catalytic/Biological
3) Thermo-physical
4) Chemical
5) Other/Combined

Oxygen

Nitrogen

Post-liquefaction

Liquid Phase

1) Centrifugal
2) Chemical
3) Biological
4) Other

Liquid Oxygen

Liquid Nitrogen

Technical Note:

Liquefaction of nitrogen is optional when gas phase separation is used. It is not clear whether liquefaction of all the nitrogen would be beneficial. Nitrogen could be used for cooling in both its gas and its liquid form.

Pre-liquefaction

Combined Phase

1) Vortex Tube
2) Catalytic/Biological
3) Thermo-physical
4) Chemical
5) Other/Combined

Oxygen

Nitrogen

Liquefaction

1) Centrifugal
2) Chemical
3) Biological
4) Catalytic
4) Other/Combined

Liquid Oxygen

Liquid Nitrogen

Available COTS (Commercial Off The Shelf) Liquefaction Technologies

Processes	Tech Options
Compressors	Lobe Compressors Screw Compressors Piston Compressors Staged Turbines Reverse Osmosis
Cryogenics	Intercoolers Heat Pumps Dry Ice Reverse Thermocouple
Chemistry	Endothermic Reactors Catalytic Converters
Physics Processes	Condensation Vortex Tubes Evaporation Pumps Ionic Wind Generator
Biological	Biological Reactors Photosynthesis Other

DESIGN PHILOSOPHY

An important aspect of innovative design is to break with traditional thinking, but do so only in constructive ways. Core to this process, is making use of the commercial market and all that it has to offer. Not just in terms of products, but also services and expertise. Simple and effective solutions are often found in trade magazine advertisements. All team members need to be aware that innovation often starts with what is readily available. Know this: 50-75% of the components needed to build a working prototype of a combined phase engine are already available for purchase. The challenge is balancing the most innovative aspects of design, with what the market can actually deliver, and successfully integrating these elements into a live, working, DEMONSTRATION.

A WORD ABOUT SCALE

- A successful CPPC is unlikely to coincide with the physical scale of other propulsion systems. Nor is the shape necessarily going to be familiar.
- We should avoid the temptation to think of this new engine as a modified version of jet engine technology.
- The laws of physics are not scale independent.
- The primary advantage of using a liquid is "energy density," this tends to indicate we should think about an engine that is substantially smaller than a conventional jet engine.
- Generally speaking, small engines can be scaled up, but large engines cannot be scaled down.

Other Miscellaneous Thoughts

How do we separate the air?

There are three primary strategies, each with a number of viable process permutations. The primary strategies are gas phase separation, liquid phase separation, and combined stage separation (some combination of the two). With each strategy we can consider gravimetric, chemical, catalytic, electrochemical, electromechanical, and biological process steps; among others. Effective approaches should be evaluated on the basis of thermodynamic efficiency and power density, as these are the most fundamental metrics we can develop for Ultra Efficiency.

Can we compress the air fast enough to keep up with the flow demands of the final stage?

This is going to be a central issue, but not a show stopper. As oxygen represents only 16% of the intake mass, we have already cut off 85% of the problem. I can't get into the details of how this can be accomplished, but allow me to point out a couple of important facts. 1) We don't have to compress all the nitrogen out of the atmosphere right away, some nitrogen can be used for cooling in gaseous form. Using gaseous nitrogen from the forward airstream does not sacrifice efficiency the way taking air off the front fan (for cooling) lowers the efficiency of conventional jets - because it's not using fuel for cooling. 2) Only the oxygen component of the atmosphere may have to be compressed in "100% net real-time." Even there, we may be able to utilize a pulsed cycle. Sure, we still need to compress nitrogen, to be used as coolant in the rocket stage: but how much of it will we need, and at what total flow rate? Just because the oxygen probably needs to run in real time (not a foregone conclusion with a propulsion system that may be throttleable) does not mean the nitrogen must also run uninterrupted cycles. 3) We can probably balance the total need for compression between nitrogen and oxygen, according to throttle requirements for specific applications. Talk about efficient! Imagine a 747 that can throttle back to a lower RPM, and power consumption, on short notice, as altitude and atmospheric conditions allow. Such a development would change the economics of the entire aviation industry. The "reason-detre" of the UEET program.

We must also consider cost.

We must bear in mind the lessons of the innovative processes we have developed! We've learned not to weight cost considerations too heavily in advance of actual commercialization, because we have proven that premature cost estimations are the primary **cause** of cost over runs. What we do instead is integrate cost into our DFM/DTC (DesignForManufacture / DesignToCost) best practices, we then rely on the strengths of our advanced process design methodologies to deliver cost effective results. It is not critical for everyone involved to be well versed in the new science of innovation, but it is helpful if everyone is at least aware that all Office of Naval Innovation Programs are meant to advance and disseminate the best of Innovation Science to the technical community at large, and to illustrate the exciting potential of this new approach to energize both the management and the practice of S&T programs.

Why an interdisciplinary approach from the outset?

As this project develops, we need to integrate a multi-disciplinary approach into the DNA of the program. As is necessarily the case with any successful innovation driven project, the effort will spawn new projects, and is likely to develop into a program of it's own. This is both a curse and a blessing. On the one hand, it's a blessing, because small investments up front lead to large quantities of downstream technology. On the other hand, managers must be careful not to lose focus of the primary objectives, as promising new areas of research are opened up by vigorous, well guided, innovation driven, experimentalism.