Response to FAA request for comment contained in- "Notification for Airborne Wind Energy Systems"

Attn, Dennis E. Roberts,
Director of Airspace Services for the FAA
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Tethered-Aviation Concept-of-Operations (TACO)
Case Focus- Airborne Wind Energy Systems (AWES)

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David Santos Gorena-Guinn and Joe Faust

KLG US Affilates
AWEIA Advisory Reps

Acronyms

AC Advisory Circular (FAA)
AIM Aeronautical Information Manual
AKA American Kiters Association
AOPA Airplane Owners & Pilots Association
ALPA AirLine Pilots Association
AMA American Modelers Association
ARPA-E Advanced Research Projects Agency-Energy (DOE)
ATC Air Traffic Control
AWE AirborneWindEnergy
AWEC Airborne Wind Energy Consortium
AWES Airborne Wind Energy System
AWEIA Airborne Wind Energy Industry Association
AWEA American Wind Energy Association
AWT Airborne Wind Turbine
CAT Clear Air Turbulence
ConOps Concept of Operations
DOE Department Of Energy
DF Drachen Foundation
EAA Experimental Aircraft Association
ECD Extreme Coherent (wind speed and wind) Direction
E-Flight Electric Flight
ESD Electro Static Discharge
ETOPS Extended Operations
EndurOps Endurance Operations
FF FreeFlight XC
FAA US Federal AviationAdministration
FAI Fédération Aéronautique Internationale
FARs Federal Aviation Regulations (USA)
FBO Fixed Base Operator (small airport admin)
FEG Flying Electrical Generator
FSDO Flight Standards District Office (FAA)
HAWP HighAltitudeWindPower
ICAO International Civil Aviation Organization
KLG KiteLab Group (cooperative R&D affiliates)

LSA Light Sport Aviation (Aircraft Category)
LLJ LowLevel Jet (meteorological jet stream)
METAR METeorological Aviation Reporting (data format)
NAS National Air Space
NASA National Aeronautics & Space Agency
NextGen Next Generation (FAA/NASA future NAS standards)
NOTAM Notice(s)To AirMen
NEC National Electrical Code
NFPA National Fire Protection Association (codes)
NIMBY Not In My Back Yard (resident stakeholder)
NREL National Renewable Energy Laboratory (DOE)
PIC Pilot In Command
PIREP Pilot Report(s)
PIC Pilot In Command
RAD Rapid AWE Development
RAT Ram Air Turbine
R&D Research & Development
SARPs ICAO Standards & Recommended Practices
SCADA Supervisory Control & Data Acquisition
SDO Super Density Operations (NextGen)
SMS Safety Management System (FAA)
SSA Soaring Society of America
sUAS small UAS
TA Tethered Aviation
TACO Tethered Aviation ConOps
TRL Technology Readiness Level (DOE TRL 1-9 Standard)
UAS Unmanned Aircraft System
UAV Unmanned Aerial Vehicle
USHPGA United States Hang @ ParaGlidingAssociation
USPA United States Parachuting Association
VO Visual Observer
VTOL Vertical Landing & TakeOff (capability)
WKM World Kite Museum
WSIKF Washington State International Kite Festival
XC Cross Country Flight

Preface to this Draft

In 2010 FAA and NASA staffers informally called on the early AWES industry to define its new "energy aircraft" types into the FAA's Category/Class system and develop a ConOps for AWES in US NAS. In response, AWEIA undertook this document, TACO, to formally address these requirements. AWEIA is an early Volunteer Association, and does not represent all points of view in AWE R&D circles. TACO represents a pilot-centric proactive cooperative approach to AWE regulation. It is the result of a two-year public process, with working drafts shared online (AWES Forum). Over a dozen AWES R&D teams and many individual experts, from all over the world, provided key input.

TACO aims toward a consensus FAA Advisory Circular, and ICAO Proposal-For-Action, informing aviation stakeholders about AWE issues and operations. TACO covers the full scope of TA, not just AWES, applying existing standards wherever possible, and is intended to merge smoothly into the NextGen Airspace ConOps. This is an open living document; AWEIA USA chapter member, KiteLab Group, builds and maintains it on a volunteer basis.

TACO 1.0 is very imperfect. Double-checking and full cross-referencing is a priority of revised editions. Thank You for patience with this initial version.

Corrections, additions, and comments invited: **santos137@yahoo.com**

CONTENTS

Executive Overview

TA can be defined as the aeronautical practices used to transfer force over distance via cables between aircraft, payloads, surface anchors or vehicles. Well-known instances include kites, aerotowing, and aerostats (moored balloons). New tethered flight concepts are expanding aviation capabilities, creating new applications, jobs, industries and novel recreations. TA even promises to generate abundant wind energy, as AWE, also known as "Kite Energy". The FAA has announced a provisional new aircraft category of AWES, to designate the rapidly evolving energy aircraft.

An AWE clean energy industry has potential to subsidize, by airspace usage fees and energy excise taxes, the needs and dreams of populations and aviation. Key stakeholders, such as pilots, developers, regulatory bodies, and government, are working together to resolve technical and social challenges. The current aviation regulatory framework is not broken, but daily protects public safety at reasonable cost, and is a sound foundation to build on.

Pilots are primary workers in airspace most exposed to flight risk, and the FAA itself is pilot-led. The standing FAA requirement for direct pilot supervision of UAS systems will hold for years yet. This ConOps is thus "pilot-centric", embracing the pilot as a key stakeholder, Upholding aviation norms and traditions. TACO is also forward-looking to eventual validated autonomous flight.

Pilots already lead in R&D of safe effective TA. They will faithfully ensure future safe of AWES operations in shared airspace. New pilots will be needed to fill the many flying jobs created.

The aerospace industry will develop large-scale systems that pilots accept and FAA inspectors certify as airworthy. Aviation and energy policy developers and decision makers are a key group to properly inform. Knowledgeable stakeholders must strive to honestly convince extended stakeholders (populations) that TA enhances society as a "good neighbor". TACO best-practice standards lay the basis for wide public acceptance.

FAA Temporary Limitations on AWES

In its Notification for Airborne Wind Energy Systems (AWES) the FAA announced a change in policy to allow for the continued development of AWES technology and to provide the FAA with data regarding these devices so that the safety and integrity of the NAS is maintained. The Agency invited comments from airborne wind energy system developers and the public toward revised policies in application of Title 14 CFR, part 77, with regard to AWES to allow the FAA to comprehensively analyze AWES integration into the NAS. The FAA determined that AWES is a unique relatively new technology supporting clean, renewable energy initiatives, and that part 101 does not currently contain the necessary provisions to address these systems.

The FAA found that whether designed with conventional 14 CFR part 101 type devices or non-conventional hybrid-type components, each AWES reviewed possessed differing attributes. These attributes included physical design, operation, airspace utilization, radar impact, etc.. The FAA is concerned with these differing attributes and their unknown impacts to the NAS, navigable airspace, and to the flying public. Therefore, the FAA concluded that each early AWES deployment needed study on a case-by-case basis, to ensure existing aviation safety.

The FAA concluded that AWES should be studied, and potential impacts to navigable airspace identified and addressed. The FAA proposed application of existing FARs that outline standards determining obstructions to air navigation or navigational aids or facilities (see 14 CFR part 77). 14 CFR part 77 is also utilized to evaluate the impact of wind turbines and other forms of renewable energy on navigable airspace. The FAA concluded that new forms of wind gathering devices will be regulated under the Obstruction Evaluation Process, as administered under 14 CFR part 77. Part 77 thus applies to current AWES projects used for R&D purposes. The FAA found that the key provisions of 14 CFR part 77 are applicable to AWES without need to amend the regulations. Permanent and operational (TRL9) AWES regulation be addressed as further evaluations and risk assessments are performed.

Pending further review, AWES developers and operators were requested to limit temporary operations to the following:

[KLG AWES "Reference Model" comments in brackets]

(1) Airborne operations of AWES should be temporary in nature for testing and data collection purposes only;

[Provision is requested for building flight hours in reliability testing. Remote operations with no shared air-use or population factors are proposed.]

(2) Single AWES devices only (e.g. no “farms or multiple simultaneous testing);

[The FAA is asked 1) to allow KLG affiliates 1/4 scale experiments of array formations. 1/4 scale is defined here as limited to 500ft AGL, with no single sail or tether element to exceed 5lbs or be allowed to constitute a dropped-object hazard; And 2) to allow side-by-side testing of scale prototypes as a basic scientific method, as long as both units together due not constitute more of a hazard (by weight, power, and/or airspace usage) than the largest allowable single unit.]

(3) AWES should be limited to a single fixed location (no mobile ground facilities);

[Many AWES in testing involve on-site mobility features. This guideline is interpreted to intend that current experimental testing only occur in fixed locations, even if the hardware has wheels for mobility.]

(4) Testing is confined to heights at or below 499 feet above ground level (AGL);

[This is a reasonable initial limitation. A few session exceptions may be requested, and reasonable Full-Scale expansion path, along a 5 year timeframe. The 2000 ft obstruction regulatory ceiling looks airworthiness-validatable in this timeframe.]

(5) Airborne flight testing of AWES will only occur during daylight hours; and

[Some amount of night operational testing of safety lighting and investigation of night winds (inversions and LLJs) is required by the critical-path to TRL9.]

(6) AWES will be made conspicuous to the flying public. (The sponsor of the AWES will provide the FAA with their marking and lighting scheme. FAA Advisory Circular 70/7460-1K (AC 70/7460-1K), Obstruction Marking and Lighting, currently does not address AWES, but may be used as a guide, as some portions may be applicable.)

[Markings will conform to or exceed the AC standard. Units will be FAA Orange and White, with FAA Red or flashing White night lighting]

[Additional KLG Voluntary Standard- Sense and Avoid capability by a PIC (and or VO)]

FAA Requested Input (Summary)

The FAA is working jointly with industry, the Department of Energy, as well as other airspace stakeholders, and believes that additional information from AWES developers would be beneficial. The information will assist the FAA as it considers long-term policies and guidance to integrate the AWES safely into the NAS.

The FAA stated several concerns regarding AWES operations in the NAS, including [comments]:

(1) Impact(s) to various surveillance systems (radars);

[AWES impacts to airspace radar are manageable by suitable designs and materials. An AWES can be naturally radar transparent (dielectric fabric and lines) and host any desired reflector or transponder in a stable position.]

(2) Conspicuity to aircraft (marking and lighting);

[KLG Large-Surfaced slow-moving AWES will have high inherent conspicuity. ANy fast moving parts of the AWES will be fully contained within the large-surface Conspicuity]

(3) Overall safety, safety to other airspace users, safety to persons and property on the ground, safety to the efficient and effective use of NAS facilities, safety to airports, safety to air commerce, and safety to the efficient operations and managing of the NAS;

[KLG concepts especially limit mass (and density) and velocity, and employ triple redundancy in all critical functions.]

(4) AWES fly-away protection (mooring cable is severed);

[Inherent flying capability, redundant tethers, "kite-killers", tether cutaway, programmed landing on site, alternate field landing, ballistic parachutes, first-responder intervention.]

(5) AWES physical dimensions per unit and per farm;

[KLG Full-Scale Spec limits Soft wings of about 100sq m and rigid wings of about 30sq m, based on current TRL8 kites.]

(6) AWES operating dimensions per unit and per farm (amt. of airspace it may require);

[A KLG scale kite farm is defined as 500ft high by 1000ft diameter. A standard early utility scale kite farm in round numbers- 2000ft high by 4000ft diameter]

(7) AWES mobility (potential for AWES to relocate from physical ground location to a different ground location); and

[AWES Units and Arrays are in principle capable of ferrying themselves to working locations and maintenance and inspection centers.]

(8) Wake turbulence or vortices of wind capturing component(s).

[This issue mainly applies to large high-velocity AWES aircraft, with interference potential inversely proportional to unit spacing. Pilot awareness of the effect, downwind in proximity to AWES operations, is likely sufficient precaution.]

The FAA recognizes various design concepts utilized by AWES developers for components of their overall AWES. These may include the components that keep the system aloft, the power generating equipment, the energy transferring equipment, the maneuvering controls, and the physical and operational dimensions, amongst others. Given these variations in technologies, the FAA seeks information from the industry to help evaluate the potential risks of permanent AWES and AWES farms operating in the NAS.

[TACO1.0 documents the current AWES state-of-the-art, to assist FAA evaluation.]

The FAA requests AWES sponsors provide information on the following by February 6, 2012. Additional information to be requested as needed.

(1) General information on a developer's specific AWES design concept and plans for operation.

[KLG tests all concepts comparatively at small scale, but is known for forward-looking Megascale AWES schemes. Broad exploration of Dense-Array kite farm Concepts and Operations is ongoing at 1/4 scale. Occasional specialized experiments will be conducted to the closest applicable standards.]

(2) What type(s) of mechanical devices are you employing to keep the system aloft?

[Ordinary Hobbyist Lifter and Power Kites, Winched and Towed Launch, Multiple Ground Winch Phased Tugging]

(3)What are the physical dimensions of the device(s) with relation to the above?

[Current 1/4 Scale Testing devices are Human-Scale. Full-Scale AWES will be Industrial-Scale, for example, ground winches and generators of about 8 cu yds in size, or more.]

(4) What kind of materials will comprise this device?

[Aloft, only polymer cables and fabric are essential; at the surface, civil engineered Earth Anchors and conventional power equipment (Winches and vehicles.]

(5) What are the operational dimensions (requirement for airspace) for the system?

[Current experiments are at 1/4 Scale- 500ft high by 1000ft diameter. Full Scale operation at 2000ft high by 4000ft diameter will follow in a few years, based as engineering milestones are met.]

(6) Is there a requirement to operate more than one device in the air?

[No. It is proposed that historic integrated kite stacks, trains, arches, and variants, [WKM, DF], be classed or typed as one device provided 1) they are comprised of many small crosslinked units working as one composite device, 2) the entire array device is flown as a single piloted aircraft, and 3) that aggregate gross weight of the array device, rather than the number of integrated sub-units, be the key regulatory metric.]

(7) What are your long-term plans for this system?

[KLG intends cooperative R&D evolution to gigawatt scale energy production under all applicable regulatory standards.]

(8) Can you comply with marking and lighting requirements?

[Yes.]

(9) Can you identify any impacts to your system when complying with current guidance for marking and lighting standards?

[Impact of Conspicuity compliance is minimal for KLG designs.]

(10) What are your plans or how is your system designed to make the system conspicuous to the flying public?

[The Dense Array Concept has the highest inherent conspicuity. FAA conspicuity standards are exceeded. Local aviation coordination would also be standard.]

(11) Safety to other airspace users and persons and property on the ground.

[Sense and Avoid would be practiced by a PIC and/or VO. The arrays will "kill" and float down at about out of the way of a wandering aircraft. Low mass, low velocity flight units of fabric and cable are the least inherently hazardous of all AWES classes.]

(12) What safety mechanisms or devices have you designed into the system to ensure all aspects of aviation safety?

[KLG embraces the SMS approach, and designs in inherent-safety features from the start- Low-Mass, Low-Velocity, Passive Flight Stability, redundant structure, double redundant manual and semi-automatic failsafe devices (Kite-Killers, Furling), PIC/VO supervision standard, etc. KLG designs for minimum inherent-risk to other airspace users, and persons and property on the ground.]

(13) What safety mechanisms or devices have you designed into the system to minimize or mitigate hazards to persons or property on the ground?

(14) What are your plans or how is your system designed to reduce a large radar cross-section and become less conspicuous to surveillance systems?

[KLG's polymer-line-and-fabric Main Specification is inherently radar transparent.]

(15) What are your plans or how is your system designed to reduce impacts to any communication or navigation systems supporting the NAS?

[KLG AWES designs are aviation need-driven. Conspicuity is maximal, radar concern minimal, and the Sense and Avoid principle is applied by a PIC and VO. As a problem is discovered, the on-site operator undertakes to remove it. The KIS "rag and string" approach promises the least impact on legacy or future comm and NAV systems.]

In addition, the FAA requested input from airspace users regarding the impact AWES would have on the NAS. They requested airspace users provide comments to the following points. Additional information may be requested upon further contact and coordination.

* What safety implications do you foresee of AWES operations with respect to your use of the airspace or your interest to the NAS?

[AWES must mitigate any adverse safety impact to maintain general standards.]

* Would you have any concerns about AWES permanently operating at altitudes above 500 feet AGL, but, under 1,999 feet AGL? If so, what and why?

[Conspicuity and proximity to high air traffic activity are key concerns.]

* If AWES were permitted to permanently operate in altitudes at or above 2,000 feet AGL, how do you foresee this as negatively impacting your missions, use of the airspace, or other interests in the NAS?

[It will essential be to evaluate impacts over time, restricting or allowing AWES according to comprehensive assessments.]

* What other concerns and/or issues might you have with respect to AWES co-existing in the NAS?

[Safety Reporting by AWES developers must begin, including Mishap Reports and Hazard Warnings.]

[AWES should not encroach on the Airspace Commons without equitable mitigation of undesired impacts. AWES implementation is not currently favored in congested airspace. NextGen SDO capabilities will be required for AWES in crowded airspace.]

Conclusions

Following a large build-up in interest and activity the FAA has released temporary policies governing experimental AWES operations. AWES R&D community discussion has been extensive and consensus standards are being drafted on many key issues. The "case-by-case" review process is seen as a reasonable standard for early AWES R&D regulation.

The FAA Advisory Circular governing Obstruction Marking and Lighting AC 70 7460 1K was accepted as the default standard for AWES conspicuity. New FAA standards for sUAS operations cover key issues common to AWES. A PIC and VO, with sense-and avoid capability are particular priorities to adopt as an AWES standard for those systems with high-consequence risk.

Mishap reporting and open Failure-Mode disclosure by developers is expressed as an essential community need. Standards for flight parameters, such as altitude, conspicuity, VFR conditions are explicitly in force by the 2011 FAA circular. Existing airworthiness standards based on aircraft mass and velocity are additionally proposed for enforcement by AWEIA, with its membership hereby on notice.

Multi-tethers and anchors are proposed as basic safety redundancy, and the determination of airworthiness should account for the lack or presence of multi-tethers, or equivalent measures, in the AWES design.

Aviation Self-Regulation

The FAA relies on all aviation sectors, via user agencies, associations, and industries, to help define, promote, and even enforce best practice of members. Safe aviation operations presided over by responsible sector self-government allows the FAA to maximize its limited resources and regulate with a light touch. Failure of any sector to ensure safety brings down the full weight of FAA enforcement.

Accordingly, AWEIA has, as part of its formal mission. a global leadership role in consensual self-regulation of AWE and related TA. TACO is AWEIA's project to coordinate Consensus Safety Standards and act as industry liason to regulators like the FAA and ICAO. AWEIA intends to instill in its members the highest safety standards in its field, anticipating and exceeding government regulations. AWEIA will petition the FAA for new Rulemaking as needed, following the successful example of EAA-FAA cooperation in creating a regulatory framework for the new LSA category. AWEIA will work within the ICAO framework to develop a core SARPs. There are already urgent R&D safety issues AWEIA is addressing, such as obligatory sharing of safety-critical failure modes and mishap reports.

No "Short-Cuts" Principle

Newcomers to AWE without a strong aviation background often express concern that aviation regulations will stifle development. The reality is that its developers who are challenged to acculturate to rigorous aviation norms if they intend to succeed. There is a niche for every level of safety culture, from small harmless wind toys, to complex powerful systems.

No TA/AWES developer should expect or demand systematic exemptions or waivers from existing regulatory standards. Exemptions and waivers should contingency-reserved for rare situations where no better alternative exists. An exception example is emergency approval of an AWES after a disaster [KLG].

Aviation Stakeholder Groups

Local governments and populations, where TA operations impact, are key stakeholders to proactively include in early planning. They will have a strong voice in shaping AWES, with a NIMBY veto power if impacts warrant.

AWEIA is just one of several aviation associations with overlapping interest in TA. AWEIA seeks to reconcile all stakeholder interests [AWEIA Code of Ethics]. AWES developers and operators are emerging from diverse aviation communities. EAA and AOPA are key pilot stakeholder representation with growing interest in the new sector.

EAA is an international membership organization and a natural incubator for innovative aircraft within small aircraft classes, especially LSA and categories like E-Flight. EAA feels squeezed from above by expansions in Class B Airspace, and now from below by AWES. The EAA suggests the use of restricted airspace to validate AWES safety and application of the FAA SMS framework [EAA, Federal Docket]

AOPA is a US legacy general aviation organization whose large membership takes a keen interest in airspace regulation. AOPA has advised caution in allowing AWES, but accepts the FAA policy notice. AOPA has identified as their critical current concern the conspicuity of an AWES, particularly its tether(s). [AOPA, Federal Docket].

The AKA represents recreational and professional kiters. Classic kiting is a major source of prior TA art. AKA is the public face of the US kiting community, with a special role to serve in AWE. Kiting culture is having an enormous foundational influence on Kite Energy, with many essential techniques already well known within small circles. Past and present AKA presidents are excited about AWE, and offer any sort of support required, by tapping into its membership network [Gomberg, AKA].

USHPA- Parafoil commonality with Kitesports and Skydiving. Special methods suited for AWES application include Step-launch, winch-launch. Decommissioned airframes may be repurposed as prototype AWES platforms [Faust].

USPA- Master Parachute Riggers will be the responsible professionals for line rigging and soft-kite platforms.

SSA is the enthusiast group closest to high-performance glider derived AWES. Case Note- Ampyx is developing glider derived "power planes", and glider champion Dale Kramer is planning Free-Flight XC demonstrations.

The AMA is responsible for safe hobbyist model aviation. Small AWES systems will become popular in the AMA technology space. AMA-FAA safety coordination is well developed.

Key Wind energy industry standards promoted by AWEA will apply to AWE operations. Case Note- Some noted players in the windpower industry are involved in AWE R&D, like US WindLabs.

ALPA and aviation carriers are not yet direct stakeholders, as commercial aviation employs reserved airspace and will stay well-separated by current standards, until NextGen is applied. As large kite farms become operational under SCADA-based piloting, the professional pilots involved are likely to have ALPA affiliation.

Applicable and Potential AWES FARs

Existing FARs cover most of the engineering and flight standards required to properly regulate the new aviation types. The classification scheme is a historical patchwork. FARs can seem vague, confused, and contradictory, but the system allows for needed wiggle-room, with exceptions, exemptions, and options at the discretion of FAA field authorities. NextGen FARs will overhaul classification, but quirks will surely persist.

Standards, Exceptions, and Exemptions

These sections propose specific Consensus Standards for regulating TA. Some of it is legacy FAA "boiler-plate" in process of being adaptation into an Applicable Standard as "an operational manufacturing/design/maintenance/quality standard, method, technique, or practice approved by or acceptable to a civil aviation authority". An Exception is a case in which a rule, general principle, etc., does not apply. There are very few justifiable exceptions to apply to TA. An Exemption is approval to be free from current regulations in 14 CFR. Minimal need for exemption of TAs from FARs is a TACO priority.

AWES Aircraft Category, Class, and Type

New Certifications for AWES.

A logical step toward proper regulation is to finally define tethered wings (large kites) as aircraft. Currently only airplanes, rotorcraft, gliders, and balloons are formally recognized as Aircraft. A tethered wing anchored in wind and/or associated motor-winch can be classed as an Engine, rated by power, for motive or output power. Ratings and Operating Limitations would be certificated just as reciprocating and rotary IC engines are. The notion of an Airframe remains the same, with the tether structural interface an added technical concern. Exotic new kinds of tethered aircraft will need to be Type Certified in a suitable new Category or special Classes.

14 CFR 1.1 defines a kite as a “framework, covered with paper, cloth, metal, or other material, intended to be flown at the end of a rope or cable, and having as its only support the force of the wind moving past its surfaces." Large modern kites are soft structures, without a rigid "framework", and any kite can be towed as a second support mode, so the definition needs updating, for example-

"A kite is a suitable winged construction intended to be flown from a tether, having as its primary support the force of wind moving past its surfaces."

Most of the profusion of potential TA design Types will sort naturally into the FAA's Aircraft/Airman/Operations Category, Class, & Type System. Categories naturally grow by adding Classes. Special TA Classes, like AWES, are proposed to supplement current Categories. A new TA Category might emerge and be formally ordered under the LSA model of classes and sets.

Like any other aircraft, TA platforms should be classified by gross-weight and airspeed, by mass-velocity physics of safety-critical "consequence". Weight and Speed are primary determinants of Class within a Categories. In general higher mass/velocity Classes have Higher Consequence Failure-Modes requiring proportionally higher standards for equivalent safety (Mortality to flight-Hours as the basic metric).

A TA Class can be widely applied, for example, many given Aircraft Types are potentially suitable or routinely modified for aerotowing, with applicable standards inherited.

Single/Multi-Engine Classes- Many TA applications have powered modes that naturally assign them to an Engine Class within a Category. The trade-off of improved reliability from multi engines is the higher required standard of Pilot training & aircraft engineering.

With respect to Certification of aircraft under the FARs, Class means a broad grouping of aircraft having similar characteristics of propulsion, flight, or landing. Examples include: airplane; rotorcraft; glider; balloon; landplane; and seaplane.

Operational classifications include: normal, utility, acrobatic, commuter, transport, special, restricted, IFR, Icing Conditions, etc.

Structural airframe systems also fundamentally categorize aircraft. A fabric "softwing" has very specific different design and operational parameters compared to any high speed rigid wing, but both can be classed as Kites.

When in doubt, best practice is sought in closely related aviation specialties, and regulated to those standards, as a ready default.

New sub-classes are proposed for major new configurations like free-flight and cross-linked flying formations. Experimental and rare aircraft types are flexibly integrated by ad-hoc classification into multiple categories & classes. Aviation is increasingly diverse and major new branches can merit a wholly new Category.

Any conventional aircraft can in principle be put on a tether, which does not negate its status as a legal aircraft of a given mass & speed envelope, but adding a tether adds operational complexity and hazard.

Provisional Sub-Classes- Tethered-Aerobatic, Tethered-Single-Engine (or turbine), Tethered-Multi-Engine (or turbine), Tethered-Normal, Utility, Sport, Ultralight, Moored-Balloon, Aero-Towed Glider, Tethered Rotorcraft.

Categories and Classes of aircraft and operations mix, overlap, or otherwise interrelate. For example, a specific type can be operated as either a Commercial or Private Aircraft, with different FARs in play. A given Type might have to conform to multiple classification standards.

Small Aircraft are defined as 12,500 pounds or less, maximum certificated takeoff weight. This is a "line-in-the-sand" for developers and regulators, as AWES grow larger, with regulatory advantages to staying small.

AWES that operate aerobatically and incur high G-loadings are Acrobatic Category (limited to 12,500lbs gross).

Tether-Weight should be counted toward rated gross weight, as a tether can weigh more than the supporting aircraft [SkySails]. Similarly, Tether-Drag is a considerable aerodynamic force, and should count against rated L/D.

Autonomous Flight of high-consequence platforms (high mass &/or velocity, especially around populations) require a proportionately more cautious rigorous path to validation and certification. AWES Autonomous Flight Certification will likely follow FARs standards applied to general flight autonomy.

AWES are generally high-duty UAS, meriting special Utility designation and Certification.

According to gross weight, AWES can be sorted into Scale-Model, Ultralight, Sport, Normal, Commuter, and Transport Weight and Airspeed Categories.

Operational altitude is a major classification criteria. Some relevant layers- 400ft for low mass low speed hobbyist model aviation. 500ft as a "floor" for general VFR aviation. Class G airspace is low altitude and variable, with higher ceilings in remote areas, 2000ft obstruction rules, 18,000ft is the defined ceiling to avoid transport aviation operations. 25,000ft is the defined threshold of High-Altitude flight, with special applicable standards.

Stall Speed is a key aircraft flight parameter, the lower the safer, with a wide range of operation desirable between max airspeed and stall speed. Fixed-Wing AWES that land at a fixed point face a challenge to not operate too close to stall on final approach, or land too hard. Sink Rate or Terminal Velocity might be a partial basis for AWES regulatory classification.

Pilot Categories, Ratings, and Training

Pilot training and testing is fundamental to aviation. Conventional pilots in AWES-shared airspace need awareness of new operations and conditions. Many AWES commercial venture starts lack formal aviation backgrounds and face acculturation along FAA approved paths. AWES pilots must master basic aeronautics, plus specialized knowledge and operational proficiency. As high-consequence risk emerges in powerful industrial-scale systems, AWES crews must ultimately meet equivalent standards of certification to Transport Pilots. See Sec. 61.31 Type rating requirements, additional training, and authorization requirements.

As used with respect to the certification, ratings, privileges, and limitations of airmen, Class means a classification of aircraft within a category having similar operating characteristics. Examples include: single engine; multiengine; land; water; gyroplane; helicopter; airship; and free balloon. New classes of airman are proposed for AWES and TA types that do not clearly fall into existing classes.

Mature TA pilot standards exist within towed gliding (including hang gliders and paragliders), banner towing, and many approved niche aviation systems.

AWES Flight Crews

sUAS Standards are generally suited to AWES operations. A PIC and VO are a minimum crew for a current large AWES. PIC and VO must judge conditions and inspect constantly. Round-the-clock watches for EndurOps must meet standards for preventing pilot fatigue. A Session Flight Plan can be followed that accounts for conditions and forecasts. Safety Training of operators must be rigorous and ongoing.

Future kite farm crews may be quite large, with most of the positions being handling and maintenance. Flight crews will serve round-the-clock in shifts [KLG].

TA Operational Categories/Classes

Flight operations vary within pilot and aircraft categories. Conditions and applications often impose specific critical constraints. Multi-modal AWES systems will blend operations of usually discrete models, as for example, a glider unmooring from its tow into its free-mode. Altitude- Obstruction Reg altitude (>2000ft), Class G preferred for AWES.

A kite tether can be considered as an "Engine", enabling wind to be a flight-sustaining power. Tether forces might thus be "rated" like engine power.

Multi-Tether Systems are comparable to Multi-Engine Aircraft, with similar engineering trade-offs. The increase in operational complexity, by added redundancy, can actually enhance flight safety, provided the pilotage is specially qualified.

Large- >12500lb, Small- <12500lb, Light, UltraLight- max 155lb, Model Aviation- max 55lb, Unregulated Toy- max 5lbs

Acrobatic Class- Aerobatic operation is a feature of some AWES, with issues of conspicuity, high cycle structural loadings and fast controls.
Novel TA/AWES Categories, Classes, Sets, and Types
The explosion of new configurations defies final classification, but can be described generally.

AWES with Surface Based Electrical Generation

Many AWES schemes minimize mass aloft by keeping electrical generation and conductors at the surface. The purest expression of this philosophy is "rag and string only", with many identified advantages to aviation safety and economics. Ground-based actuators (winches) can be massive industrial grade machinery, without the delicate margins of flyable servos. Radar clutter, com link dependence, inspectability, high mass-velocity, and many other issues are mitigated. There will still be enormous challenges to safe operations as mechanical power scales grow.

AWES with Electrical Power Generation Aloft

Electrically Conductive AWES Tethers and generators require added standards to address inherent safety issues. A general suggestion is to apply terrestrial electrical code and fire safety standards, as a default baseline, with special aviation standards overlaid.

E-Flight is a fast progressing new category of general aviation. Tethered E-Flight will share many of the existing and pending standards. E-VTOL will inherit key standards of existing VTOL.
Case Note: Sky WindPower, Inc, is well regarded for its study of the electric quadrocopter AWES concept space. Makani Power, Inc, leads in developing large advanced composite autonomous aerobatic E-VTOL AWES. The Makani models are useful benchmarks for regulation study, with data being generated under a DOE contract.

Autonomous AWES

Autonomous Flight is slowly maturing as a viable aviation option. Many AWES teams are working to automate flight operations to avoid human piloting. Tethered autonomy has both favorable and adverse aspects. Tether dynamics add aeroservoelastic uncertainty.

Developing flight control software is an exacting slow process. AWES engineers must create code to "clean-room" standards and have it formally validated. Sensory and situational uncertainty are persistent problems. Exception handling is a critical challenge. Decision to relaunch a system after an automatic shutdown is a "tough call" to automate. Meanwhile, human piloting will rely as necessary on existing avionics, and supervised autopiloting.

SARP is the conceptual paradigm for pilot-supervised automation.

Cellular Aerial Arrays

Formations of TA aircraft joined by tethers into dense-arrays is a major AWES configuration class. A goal of dense-array methods is to greatly enhance general aviation safety and reliability by avoiding airspace (and land) sprawl for an equivalent power capacity. Many functional units can be aggregated to fly as one well-integrated flight control process, as opposed to many independently (auto)piloted units.

Arrays can incorporate any of the many classes of AWES units. The array can constrain units into a high "aggregated stability" whereby the momentary instability of any single unit is cancelled by the normal action of neighbors. High Conspicuity and redundant surface connections are safety advantages, but given a large arrays, an unlikely worst-case mishap of a dragging breakaway could be catastrophic. The highest professionalism and redundant levels of "killability" will be required for these vast flying megastructures.

Case Note: TUDelft and KLD are R&D leaders in the design-space of cross-linked formations of AWES units.

High Altitude Kite Flight

Even a century ago, kites reached altitudes in excess of 30,000ft. While current art and short-term economics favor low-altitude AWE, a new round of high-altitude kite aeronautics is is poised to explore "fuelless aviation" applications even to around 100,000ft. These will be demanding experiments conducted by top aerospace teams, as approved by the FAA on a case-by-case basis.

Currently, stretching tethers to high altitudes is an unacceptable hazard to all classes of aviation in shared airspace. The consequences of breakaway and runaway are aggravated. Persistent high Altitude TA must remain in restricted airspace and await NextGen capabilities to expand operations.

Existing missile ranges are proposed as an ideal venue for high-altitude TA testing, on a time-shared basis, as such restricted airspace is not often too intensively used for rocketry.

"Free Flight"- Wind Powered Aviation

Free-Flight is a frontier of aviation based on two or more wings tethered together. Its been shown with small models that if each wing flies in its own wind, the tether stretched across a wind gradient, they can work in opposition and sustain flight in any direction. Unlike traditional soaring dependent on thermals or terrain, Free-Flight can be sustained ordinary surface wind gradient or any sort of wind shear, like around LLJs and inversions. It may be a revolutionary basis for future XC flight.

Case Note: National champion glider pilot and aeroengineer, Dale Kramer, proposes a cross country demonstration of Free-Flight by tethering his high performance glider to a large kite farther above. By working glider against kite its predicted he can fly almost indefinitely without fuel. The FAA traditionally accommodates such unique aviation feats that advance aeronautical knowledge on a case-by-case basis, with only the highest level of skill and expertise allowed. There will be many unique aeronautical feats to attempt along these lines.

Tethered Rotorcraft

Many prototype and proposed tethered rotorcraft are proposed for AWES. Some are E-helicopters whose motors also generate, and others are basic autogyros modulated to pull against loads, as "Traction Rotors".

General rotorcraft design and operational factors as currently defined will apply to the new rotorcraft, with tether factors added.

Case Notes- Seattle-based SkyMill is an example of a serious AWES Traction Rotor developer and has an MOU with Boeing and engineering affiliations with Sikorsky.

SkyWindPower is a large-quadrocopter AWES developer with academic roots and a Huntsville-centered aerospace team.

Aerobatic AWES Aircraft

Many AWES concepts propose aerobatic flight to sweep crosswind in kite mode. A figure-of-eight pattern is common and ranges from a short non-aerobatic "dutch roll" oscillation to full "lazy-eights". Also common is a fully aerobatic circular "kite loop" pattern.

Under FAR §91.303 and AC AC 91-48, Aerobatic flight is defined as intentional abrupt change in an aircraft's attitude, abnormal attitude, or abnormal acceleration, not necessary for normal flight. Restrictions include aerobatic flight over urban areas, outdoor assenblies, Within surface areas of Class B, Class C, Class D, or Class E airspace designated for an airport; Within 4 nautical miles of a Federal airway; Below 1,500ft AGL; or if flight visibility is under 3 statute miles.

Given Part 77's altitude ceiling of 2000ft, and the aerobatic minimum of 1500ft, suggests a default operating zone of 500ft. This may be a desirable AWES design constraint to enforce.

AWES in stable flight, with highly constrained sweeping sub-elements, may or may not be found aerobatic, on a case-by-case basis, as determined by mass-velocity and other safety metrics.

Case Note- Joby Energy has merged under Makani Power and this team is the leader in the aerobatic E-VTOL AWES concept-space.

Aerostats

The term Aerostat is associated with Moored Balloons, but logically extends to persistent tethered electric aircraft or kite flight. Aerostats have many applications and usage is likely to increase.

Once common as wartime Barrage Balloons, Moored Balloons are making a comeback as radar stations (to 18000AGL) and for low-altitude advertising. Many AWES designs employ Moored Balloons for persistence aloft. Moored balloon regulations are mature and may represent an early regulatory approval path for AWES.

Persistent E-Flight is being shown practical by means of a conductive tether. Kites can keep station in calm by towing in circles from vehicles or by phased tugs from fixed winch networks. This is a new aerostat class, suited for AWES application.

AWE Ferrying Operations

AWES may involve self-powered or towed air ferrying to operational or maintenance/inspection locations. Such transport may need special clearances and flight planning, akin to moving oversized cargos on roadways, in the case of large or far-flung configurations [KLG].

Classic Kite configurations

Traditional kite methods are powerful and instructive. The following traditional multi-kite classes can be identified- Stack, Train, and Arch [WKM]. A new class is emerging from kiting, dubbed a "Cloud", as a 3D cluster of cross-linked kite structure [WKM].

Given the enormous historic experience with classic kites, regulators can have high confidence in domain expert-predicted safety.

Existing TA Operational Norms and FARs

Many existing FARs apply directly to TA or can be adapted. Part 101 contains "heirloom" seeds of many TA regs to come, but are overdue for upgrades to cover holes in safety and to allow for enhanced capabilities. Requiring certificated airworthiness substantially within current regs will prevent AWES R&D from inadvertently creating a menace.

It is proposed by the FAA that early operational AWES operate under 14 CFR part 77 Obstruction regs such as govern Antenna Farms, but this model is partial. For example, an antenna-farm Obstruction is also regulated under mast & tower structural and electrical codes outside the purview of the FAA. Towers lack many inherent hazards related to aircraft airworthiness & a potential to crash far afield (runaway). An AWECS is not a tower & needs to comply with Airworthiness Standards.

AeroTowing and Banner-Towing Precedents

Legacy TA will persist under existing FARs. A constant exchange of technology will occur with new types of TA, and many of the old rules will still apply. Aerotowing continues as a major method of launching gliders and as a design option for certain situations. An active world record category involves towing as many gliders as possible from one tow-plane. Utility towing of cargo and passengers might make a comeback in the future due to economic or practical considerations. Traditional Banner Towing Operations continue to evolve by incremental hardware and operational improvements. New types are emerging; for example, the lifting of mega-flags by helicopter.

Draft FAA sUAS Regs

AWES are UAS. sUAS rulemaking is proceeding and the FARs expanding accordingly. Draft rules call for a PIC and VO crew. A misconception in the AWE field is that autonomous operations will be permissible in a short time-frame. The safer bet is that many years must pass before the required Airworthiness is validated and Certificated, and that UAS and sUAS PIC/VO rules will apply.

Parts 101 and 77

PART 101 - MOORED BALLOONS, KITES, UNMANNED ROCKETS AND UNMANNED FREE BALLOONS

Part 101 sections below are still being edited for brevity.

The existing Kite, Moored Balloon, and Unmanned Free Balloon Regs are partial models for Tethered Free-Flight. Not that Part 101 is being rapidly superseded by new FAA AWES Guidelines.

Part 101 applies to any kite that weighs more than 5 pounds intended to be flown at the end of a rope or cable...including a gyroglider attached to a vehicle on the surface of the earth is considered to be a kite. No person may conduct operations that require a deviation from this part except under a certificate of waiver. No person may operate a moored balloon, kite,... in a prohibited or restricted area unless he has permission from the using or controlling agency, as appropriate.

101.7 covers "Hazardous operations" and has a key catch-all clause- "No person may operate any moored balloon, kite,... in a manner that creates a hazard to other persons, or their property." It goes on to assert "No person operating any moored balloon, kite,... may allow an object to be dropped therefrom, if such action creates a hazard to other persons or their property."

The next subparts apply to the operation of moored balloons and kites. A person operating a moored balloon or kite within a restricted area must comply only with 101.19 and with additional limitations imposed by the using or controlling agency, as appropriate.

101.13 Operating limitations. (a) Except as provided in paragraph (b) next, no person may operate a moored balloon or kite- (1) Less than 500 feet from cloud base; (2) More than 500 feet above the surface of the earth; (3) From an area where surface visibility is less than three miles; or (4) Within five miles of the boundary of any airport. (b) Paragraph (a) of this section does not apply to the operation of a balloon or kite below the top of any structure and within 250 feet of it, if that shielded operation does not obscure any lighting on the structure.

101.15 Notice requirements. No person may operate an unshielded moored balloon or kite more than 150 feet above the surface of the earth unless, at least 24 hours before beginning the operation, he gives the following information to the FAA ATC facility that is nearest to the place of intended operation: (a) Names and addresses of owners and operators. (b) The size of the balloon or the size and weight of the kite. (c) The location of the operation. (d) The height above the surface of the earth at which the balloon or kite is to be operated. (e) The date, time, and duration of the operation.

[The above continues to be a workable system for certain small simple low-risk AWES R&D, say by a school youth team.]

101.17 Lighting and marking requirements. (a) No person may operate a moored balloon or kite, between sunset and sunrise unless the balloon or kite, and its mooring lines, are lighted so as to give a visual warning equal to that required for obstructions to air navigation in the FAA publication "Obstruction Marking and Lighting".

(b) No person may operate a moored balloon or kite between sunrise and sunset unless mooring lines have colored pennants or streamers attached at not more than 50 foot intervals beginning 150 feet above the surface of the earth and visible for at least one mile.

[Conspicuity Comment- Three-mile visibility standard is proposed to supersede the one mile minimum, based on higher general aviation traffic and airspeeds and likely proliferation of AWES.]

101.19 Rapid deflation device. No person may operate a moored balloon unless it has a device that will automatically and rapidly deflate the balloon if it escapes from its moorings. If the device does not function properly, the operator shall immediately notify the nearest ATC facility of the location and time of the escape and the estimated flight path of the balloon.

[A Kite-Killer operational model]

Subpart D - Unmanned Free Balloon Operations 101.31 A person operating an unmanned free balloon within a restricted area must comply only with 101.33 (d) and (e) and with any additional limitations that are imposed by the using or controlling agency, as appropriate.

101.33 Operating limitations. No person may operate an unmanned free balloon- (a) Unless otherwise authorized by ATC, in a control zone below 2,000 feet above the surface, or in an airport traffic area; (b) At any altitude where there are clouds or obscuring phenomena of more than five-tenths coverage; (c) ... where the horizontal visibility is less than five miles;

(d) During the first 1,000 feet of ascent, over a congested area of a city, town, or settlement or an open-air assembly of persons not associated with the operation; or (e) In such a manner that impact of the balloon, or part thereof including its payload, with the surface creates a hazard to persons or property not associated with the operation.

[More model specification of "Kite Killers" following the free balloon model-]

(a) No person may operate an unmanned free balloon unless- (1) It is equipped with at least two payload cut-down systems or devices that operate independently of each other; (2) At least two methods, systems, devices, or combinations thereof, that function independently of each other, are employed for terminating the flight of the balloon envelope; and (3) The balloon envelope is equipped with a radar reflective device(s) or material that will present an echo to surface radar operating in the 200 MHz to 2700 MHz frequency range. The operator shall activate the appropriate devices required by paragraphs (a) (1) and (2) of this section when weather conditions are less than those prescribed, for operation under this subpart, or if a malfunction or any other reason makes the further operation hazardous to other air traffic or to persons and property on the surface.

(b) No person may
operate an unmanned free balloon below 60,000 feet standard pressure altitude between sunset and sunrise (as corrected to the altitude of operation) unless the balloon, attachments, and payload, whether or not they become separated during the operation, are equipped with lights that are visible for at least 5 miles and have a flash frequency of at least 40, and not more than 100, cycles per minute.
(c) No person may operate an unmanned free balloon equipped with a trailing antenna that requires an impact force of more than 50 pounds to break it at any point, unless the antenna has colored pennants or streamers that are attached at not more than 50 foot intervals and that are visible for at least one mile.

[The standard above suggests a 50lb breaking-strength metric for partial exemption of minor single kitelines]

(d) No person may operate between sunrise and sunset an unmanned free balloon that is equipped with a suspension device (other than a highly conspicuously colored open parachute) more than 50 feet along, unless the suspension device is colored in alternate bands of high conspicuity colors or has colored pennants or streamers attached which are visible for at least one mile.

101.37 Notice requirements. (a) Prelaunch notice : Except as provided in paragraph (b) of this section, no person may operate an unmanned free balloon unless, within 6 to 24 hours before the operation, he gives the following information to the FAA ATC facility nearest to the place of intended operation: (1) The balloon identification. (2) The estimated date and time of launching, amended as necessary to remain within plus or minus 30 minutes. (3) Location of the launching site. (4) The cruising altitude. (5) The forecast trajectory and estimated time to cruising altitude... (6) The length and diameter of the balloon, length of the suspension device, weight of the payload, and length of the trailing antenna. (7) The duration of flight. (8) The forecast time and location of impact with the surface of the earth...

101.39 Balloon position reports. [This general procedure is suited to realtime BreakAway Emergencies] a) Each person operating an unmanned free balloon shall: (1) Unless ATC requires otherwise, monitor the course of the balloon and record its position at least every two hours; and (2) Forward any balloon position reports requested by ATC. (b) One hour before beginning descent, each person operating an unmanned free balloon shall forward to the nearest FAA ATC facility the following information regarding the balloon: (1) The current geographical position. (2) The altitude. (4) The forecast trajectory for the balance of the flight. (5) The forecast time and location of impact with the surface of the earth. (c) If a balloon position report is not recorded for any two-hour period of flight, the person operating an unmanned free balloon shall immediately notify the nearest FAA ATC facility. The notice shall include the last recorded position and any revision of the forecast trajectory. The nearest FAA ATC facility shall be notified immediately when balloon tracking is re-established. (d) Each person operating an unmanned free balloon shall notify the nearest FAA ATC facility when the operation is ended.

14 CFR Part 77 - OBJECTS AFFECTING NAVIGABLE AIRSPACE

The FAA has provisionally ruled-

"Persons proposing to conduct temporary airborne testing of AWES for data collection purposes must provide notice to the FAA pursuant to 14 CFR 77.13(a)(1), requiring notice of any construction or alternation of more than 200 feet above ground level."

This notice is not interpreted to preclude current allowable operations of TA, such as Tow-Launch of Gliders, Banner-Towing, Hobbyist Kiting, etc., which can serve as surrogate data sources, unless the study compounds risk.

Nor is AWES testing seen to be prohibited under 200ft, provided the key rule of Part 101 is met- "No person may operate any moored balloon, kite, ... in a manner that creates a hazard to other persons, or their property."

FAA can make the following determinations- No Objection, Conditional Determination, and Objectionable. Obstructions are identified by conflicts with "Imaginary Surfaces" partitioning airspace, particularly in proximity to Airports.

Other 14 CFR Parts

The FAA regulates skydiving activity under "Parachute Operations" Part 105 (14 CFR 105). Flight operations for skydiving are conducted under Part 91 "General Operating and Flight Rules" (14 CFR 91).

FAA Advisory Circulars provide additional guidance about flight operations. Banner-Towing & Glider Aero-Towing regulations inform equivalent operations in other applications.

Recreational NAS use covered by FAA Advisory Circular (AC) 91-57; generally limits operations to below 400 feet AGL well separated from airports and air traffic. This is the appropriate airspace for virtually all current AWE developers to conduct most experiments without constituting a menace.

Three acceptable means of operating UASs in the NAS: 1) within “restricted airspace: or under a Special Airworthiness Certificate (2) Experimental Category or (3) Certificate of Waiver or Authorization (COA). A COA authorizes an operator to use defined airspace under specific provisions unique to the operation. It may require Visual Flight Rules (VFR) & operation only &/or during daylight. COAs are issued for a specified time period; one year typical. COAs require coordination with air traffic control & may require a transponder in certain types of airspace.

Mishap and Accident Reporting

Aviation safety historically depends on shared safety knowledge. Voluntary and enforced safety reporting is now well established.

It is essential that the pioneering TA/AWES community voluntarily report safety related mishaps and accidents according to existing aviation standards for such data. There is an unfortunate practice on the part of some commercial ventures to consider such information as private, but aviation safety shortcuts are not a true business advantage, and the unintended result may be loss of innocent life.

Failure of voluntary AWES Safety Reporting will provoke mandatory standards.

Sense and Avoid Standard

A sUAS's current inability to autonomously follow "sense and avoid" rules means a ground observer (PIC &/or VO) must maintain visual contact operating in unrestricted airspace. The PIC/VO should maintain aural vigilance in a quiet enough setting (no loud machinery) to detect airplane intrusion before visual spotting. "Sense & avoid" UASs requirement currently means a PIC and VO, plus dive or kite-kill capability. Possibility of special IFR Rules clearances, for example, a higher operational ceiling during graveyard shifts to help AWES bridge night-time surface inversion calm.

TA Daily Operations

Tethered Aviation operations entail general and particular hazards. A tether is a vulnerable and dangerous obstacle extending almost invisibly over large distances. Conspicuity an established requirement.
Weather is a key AWES parameter, with a close dependence on forecast conditions.

Filing daily NOTAM are an essential procedure in many airspace regions. PIREP are another messaging tool. Mayday is the most extreme instance reserved for immediate human peril.

Separation, Avoidance, Visibility, & Education (SAVE) is a useful mnemonic for the basic principles of safe TA operations. S is for passive Separation; the relegation of TA operations to remote low-traffic airspace; A is for Avoidance; the effective evasive capability of a TA platform (ie. "kite-killers"). V for Visibility is the standard for obstruction markings, transponders, radar-reflectance, etc.. E for Education is the requirement to appropriately inform & train all pilots operating in proximity to TA, as well as the special Type-Rating knowledge a TA PIC needs.

Dense Arrays- Super Density Operations (SDO)

A major class of TA is cross-linked wings in arrays. Such arrays are calculated to utilize airspace up to a hundred times more efficiently than single-line AWES. The "tether-scope" requirement of single-line systems means they operate too sparsely to scale greatly,

Multiline Arrays also have key safety advantages over single line systems. Redundancy of tethers makes flyaway safely improbable. Land and airspace is conserved, minimizing obstruction issues. Conspicuity is greatly enhanced.

The 155lb UltraLight Vehicle Maximum is proposed as a Consensus Standard AWE wing unit maximum for large arrays. This allows for considerable power per unit (>100kW).

Formations of cross-linked soft wings, organized almost like a micro-chip and firing in metachrony, may be "the look". Such lattices may aggregate enough power to drive the largest ground-based generators; and even retrofit legacy power-plants (esp. Nukes), and as kite-hybrids (to throttle-back Gas and Coal Turbines).

Special AWES Sub-Classes

Many AWES concepts involve special unstandardized methods that will evolve into well-defined classes with consensus standards.

Some specific methods to note- Traction-Rotor, Wingmill, Varidrogue, Pilot-Kite, etc.

Future ACs will detail these specialty issues.

Hazard Mitigation

A hazard is defined in FAA Order 8040.4 as a "Condition, event, or circumstance that could lead to or contribute to an unplanned or undesirable event." Hazard Analysis is the process of indentifying hazards. Risk Assessment is the process of quantifying identified hazards.

Special TA Risks

A tether is a significant flying obstruction hazard requiring complete avoidance. Tether geometry and operational methods are unique features to account for, with useful similarity to standard geometry flight trajectories and special aviation operations like free-ballooning and skydiving.

Poor Conspicuance

Mid-Air Collisions- Tether trajectories and aerobatic patterns of fast moving AWE kiteplanes can catch a VFR pilot unawares, otherwise Mid-Airs are not an inherent hazard with high conspicuity AWES. Sense and Avoid is the Consensus AWEIA Standard. UAS must give way to all manned aircraft.

Sparse single-line arrays may distract encroaching pilot with one unit while another unit goes unoticed. Dense clustering of the units seems like a safer configuration.

MegaScaling

Kites are the largest aviation structures and the multiplication of powerful forces can make them inherently dangerous. The largest wing ever created was a 17,000sqft monster that caused a fatality within minutes of first flight [WKM].

Long tethers are megascale structure and caused power blackouts and stopped trains and steamships [WKM, DF]

Breakaway

Multi-Line Tether redundancy is the most basic precaution from Breakaway. If any line parts, remaining line ratings must exceed the new line break load-case.

Breakaway of a passive kite from its anchor generally results in the kite gliding down to the surface in large circles. A kite circling down in wind generally lands 4x its altitude downwind from its breakaway point.

Tether Dragging is a most dangerous condition of a kite dragging its anchor or "junk" with enough resistance to sustain flight for an indefinite distance, possibly even for hundreds of miles. This hazard should be known and planned for by first-responders. A tether cut-away system can mitigate dragging hazard.

Flying Mass (Generators, etc.)

The fundamental determiner of flying generator risk is mass times impact velocity. Extra safety-criticality exists when the generator is also required to maintain flight by motoring.

Niche concerns exist. The FAA discourages unpressurized Magnetos above 14000ft, due to corona discharge "cross-firing". Cyclic high G-Loadings can cause generator windings to fail early by rubbing way insulation, especially operating near thermal limits.

Conductive Tethers

Electrical Hazards of many High-Voltage systems are well known and subject to well defined standards. AWES operations add dimensions of risk and complexity, but a rough consensus exists that the problems will be overcome by careful engineering. Electrocution risks must be virtually eliminated by a combination of proper design and sound operational practices.

The NEC is recommended as the baseline electrical code governing high voltage operations, and other NFPA codes for fire safety, as applicable.

Issues of concern include- Shorted Power Transmission, Equipment Fire, WildFire, Lightning, Structural mismatch (creep, mixed elastic modulus), Polymer composite Thermal Limits, Thermo-Resistive Runaway, Ground Contact during Flight Operation, Salt Environments. etc..

Weather Hazards to AWES

AWES operations must reliably adapt to meteorological extremes, anticipating fronts, storms, icing conditions, and so on.

Turbulence

A zoo of CAT, ECD, gustnados, virga, breaking gravity waves, etc. can potentially upset AWES flight.

Suitable control limits and load cases must be defined (especially by downward and rearward bursts).

Icing

Soft Kites have been shown to naturally shed ice (KiteLab Group). Rigid airframes will require landing in icing conditions, or standard deicing gear.

Snow

AWES will require means of coping with snow on a case-by-case basis. Buildup on wings during ground phases and site mobility are two obvious problem cases.

ESD

Kites and Moored balloons often experience extreme electrostatic charge (Saint Elmo's Fire). This Corona Discharge can affect electronics and burn semiconducting surfaces (like salt infused dielectric materials. This will be an important hazard to validate solutions for.

Lightning

Lightning hazard is best assessed case-by-case, with normal considerations, and tether-specific risk. Conductive tethers present a potential path for lightning, and polymer tethers can melt, causing breakaway. Multiple dielectric tethers seem advantaged, but data is scant.

Hazardous Flight Dynamics

Aerobatic Operations are intentional flight dynamics covered elsewhere. Unintended inherently hazardous Flight Dynamics include Buffet, Divergence, Slack-Tether, Tether-Snub, Actuation Saturation, Surge loads.

Wireless Control Link Dependence

Wireless control links are vulnerable to jamming and other failures and must be rigorously validated. GPS and other data systems cannot be exclusively depended on for flight. Default failsafe modes are needed for any communication failure.

Radar "Clutter" Concern

The current air traffic control and civil defense system depends on legacy radar and it will take a decade or two before this reality changes.

Radar integration requirements and consensual best-standard is emerging; that an array or kite farm have at least one corner reflector in stable flight (not aerobatic) with a standard transponder. What the FAA seeks to prevent is sprawling clouds of fast moving clutter creating a hazard for existing aviation. Pilots are a powerful political force in airspace issues who also will not allow a degradation of safety standards.

"Decloaking"- Emergency radar reflectance upon breakaway to Free-Balloon standard;

Case- The SkySails Control Pod is a small radar target with a stealthy shape (no corner reflector surfaces) and would be fairly easy to coat with radar absorbing "blackball" paint. Of course, the parafoil itself is almost invisible to radar naturally, if the cloth sizing does not contain aluminum or other metallic ingredients.

Terminal Collision Avoidance System (TCAS)

TCAS III interrogates airborne radar beacon transponders and provides traffic advisories and resolution advisories in the vertical and horizontal planes to the pilot.

NextGen Transponders

The FAA will require the majority of aircraft operating within the NAS to be equipped with some form of ADS-B Out by January 1, 2020, as part of NextGen implementation. ADS-B is also a basis for "self-separation" of AWES in overlapping operation, to reduce airspace sprawl.

Control Loss

Actuator Saturation is a working actuator, such as a control surface, so overpowered by extreme conditions as to be unable to effect a control outcome.

Improper Attitude of an aircraft is when it diverges from an intended orientation. In single tether dynamics, consistent attitude is inherently tricky to maintain, as compliance is high. On the other hand, multi-tethers "staked apart" can constrain attitude to a narrow range.

Fail-Safes

A human pilot is currently indispensable to identify and recover AWES system upsets. This requirement will only ease as progress in reliability and flight automation occurs.

Passive Stabilities are inherent aerodynamic design features that tend to stabilize the aircraft in the absence of any active control. They include Dihedral, Keel, Snowplow Stability (Wing sweep), Tail/Drogue, and Y-Bridling.

Low Sink-Rate- Floaty low-mass low-wingloading aircraft are favored in a control-loss case.

Aggregated Stability- Cross-linked formations can enjoy a statistical stability, a "safety in numbers" higher than with individual units. This is seen when many marginally stable kites (like Fighter Kites) are flown in branching trains; the collection of kites flies stably, while any single kite would soon crash.

Spread-Anchor Stability- AWES can be "staked-out" across a kite-field, using the ground itself for powerful pitch-roll-yaw stability. This spread stability principle also enables far denser airspace utilization. by reduced positional uncertainty.

Safety Suspension of Unstable Elements- A sedate stable airborne platform can host less stable high-performance units suspended underneath.

Back-Up Systems- Automated Ballistic Parachutes might perform "saves" of high-. mass falling objects.

E-VTOL Concerns

Settling-Under-Power, Thermal Shut-Down, and Loss of Back-Up Power are some special design and operational concerns.

Rotor Concerns

Many Helicopter and Autogyro standards apply. A potential for snagging tethers with rotors is a design and operational concern.

Rope Drive Concerns

Moving cable power transmissions have dragging, cutting, and burning potential.

Site Concerns

Bases must cope with Storms, Hail, Ice, Lightning, Wildfire, and so on. Nesting Birds and Mud Daubers (pitot tubes). Bird Droppings can degrade a wing's lift below minimum specs.

Security concerns range from random vandalism to targeted sabotage. The nature of a threat, the inherent risk of an operation, and applied counter-measures all figure.

First Responder Access

AWES operations shall provide for clear and safe first-responder field access. An approved responder plan shall be filed and maintained with local fire and medical authorities.

Communications with ATC

AWES will be subject to the same standards of radio communications as other air traffic in its airspace.

Developers shall be contactable by, and be ready to contact, ATC, in the event of an emergency.

Mid-Air Collision Hazard

Airframe-to-Airframe, Airframe-to-Tether.

Bird-strike to a high speed AWES can endanger flight.

Safety Aloft (Kite-Based "Manlifting")

"Manlifting", as human flight is called in classic kiting, has been a taboo activity in modern kiting since the tragic death of a a leading figure [Eideken]. Its pretty much the only strict rule the AKA has; its million-dollar-per-instance member insurance policy is void when kites are used for human flight. In the many new kite sports people are flying and dying. Instances of sustained manlifting should be regulated under manned piloting standards.

In other flight domains, such as paragliding, rigorous standards exist for tethered human flight (Tow Launch). A high standard of training and measures like a reserve parachute typify safe tethered human flight. Tethered human flight operations are consensually considered to be higher-risk, requiring a higher standard of airmanship.

Basic Safety Precautions for AWES

TA Design Defaults

In the absence of extended testing, pessimistic safety margins are advisable.

Owing to tether effects like chaotic flight surges and slack-jerk, an 8 to 1 calculated safety-margin over the working load-case covers surge loads to single-line structure. Multi-line structure can employ somewhat relaxed margins.

All line, webbing, and fabric work to Master Rigger's standards covers most kite-surge and line-wear. These margins are higher than conventional aircraft to account for EndurOps conditions.

No Personnel should "stand in the bight," that is to say, occupy a position where impact can occur with a parting anchor or mechanical fitting under high loading.

AWES Crashworthiness and Crash Resistance

Crashworthiness is an aviation standard related to crash survivability, and can be specially defined as the ability for the airborne platform to crash without harm to people, including operators and populations.

Crash Resistance is definable as the natural ability of a kite-like platform to "crash" in ordinary use, without harm to property or itself, and be able to "hop right back up".

The primary design and operational challenge is to "delethalize" every aspect of an AWES, by integrated systems engineering. Testing is required to best establish the extent to which hazards exist and how they can be mitigated.

In general, rigid high-mass high velocity aircraft are less crashworthy or crash resistant than low-mass low-velocity platforms. like soft-kites.

Operational Safety

Multiple Lines are a basic AWES redundancy, and a natural feature of most multiple kite arrays. Preventer Lines are a key back-up tool. Kill Lines and Weak Links are traditional "fail-soft" methods.

As tethered aviation grows along with existing airspace congestion, the mid-air collision risk by tethers will grow, demanding special precautions. Capability for an AWECS to "sense and avoid" is the primary defense against an airspace intrusion, but with limited reliability, so other measures must provide redundant protection for the worst cases.

Personnel Protection

AWES begins as a hazardous pioneering field. Every effort should be made to eliminate or control workplace risk. Required worker precautions will range from simple protective gear like gloves and hook knives in the case of simple systems to armored vehicles, tunnels, and bunkers, in the case of high-mass high-velocity operations.

Ground Safety

Safety Aloft

A common requirement for "perpetual" flight of large AWES will be for human operators to be able to climb aloft for maintenance and repair operations.

Safety Nets, such as trapeze artists train with, are an option for some designs. Property and populations under an EndurOps AWES might also warrant protective netting.

A reserve Parachute can be apex-hung passively-ready over a gondola or person, for quickest inflation. Such a rig fills a key gap in the Death Zone between 10m and 200m (minimally safe base-jump). Ballistic chute systems have a place in manned TA, but may entail too much weight and cost for economic energy aircraft.

Body Harness and Safety Tethering following industrial climbing or mountaineering practice. Helmet, gloves, conspicuous clothing, etc. as needed. Body Armor has a general protective effect. Cutters such as a Hook Knife or ax can be essential. A Life Jacket requirement exists over water. Clothing and accessories should be free of snags. Fire-Safety principles apply according to specific risk.

Reserve Parachute. Minimum altitude allows time to deploy the chute, but with considerable risk. High altitude makes a parachute jump routine, with automatic deployment devices available.

Large stunt-fall Airbags and climbers' crash cushions may find some use. Its possible a large parafoil can serve as a track-to airbag for a freefalling "Sky Monkey". Special airbags or spring legs can make landing modules safer.

Flying and Falling Hardware is a major hazard. Accidental dropping of any object should never occur. Dangerous droppable mass should be padded and multiply secured; by added Lanyards as needed for redundancy.

Protecting Recreational and General Aviation

Conspicuity and Pilot Awareness are primary protections. "Sense and Avoid" is a key capability. Operation in remote areas is favored. Air traffic in regular proximity to TA, may employ special precautions.

Some historic military aircraft had line cutters added, to cope with barrage-lines. This precaution will make a comeback around intensive kite operations. Preventative design is to fair profiles, adding glide rails or stays to allow lines to slide past airframes.

Helicopters are uniquely at risk from ordinary kite tethers, as they generally operate a low altitudes with a large unprotected rotor. Collective pitch links at the rotor hub are especially vulnerable to being "frozen" if wrapped-up in kite line. It may pay to protect rotor links from various kinds of lines by means of cutters based on sharp blades, abrasives, or resistive heat. Exhaust heat could protect against UHMWPE wraps, since its melting temp is low; on the other hand, a fire risk might result. Some helicopters already have partial cutter protection, a line cutting device on the top of the cabin, but there are other snag-points to protect, like crooks formed by landing skids.

Collisions with a low-mass low-tension tether can be gentle upon contact but progressive in action. A faired aircraft might brush-past without snagging, recovering attitude. In many future cases more risk may ensue from cutting a tether than letting a colliding aircraft hang in a tangle. It may be practical for a flight crew to escape or be rescued, and their ensnared aircraft recovered with only minor damage. Dramatic mishaps with happy endings could occur with Fail-Soft measures.

AWES Flight Operations

Launching and Landing are the riskiest routines in TA. Some system designs will call for high avoidance of frequent take-offs and landings [Joby Energy], and others will seek to eliminate all hazards, to enable frequent hops up and down. Aerial Assembly by docking units may be standard for certain large arrays. The docking aircraft may come form nearby airports, in some concepts [KLG].

Cascaded launching and landing sequences will be common {KLG].

AWES will vary operations according to wind conditions. Aerobatic systems will park in high wind [Makani Power], to limit surge. "Low tech" systems will furl or change sails as condition change [KLG].

Operation in IFR Conditions

It is presumed AWES will be validated to operate during IFR conditions: at night and during other low-visibility conditions. One advantage is that AWES will remain on station, and not be wandering in low-visibility.

Night Operations

AWES will seek to tap common LLJs that form over night-time surface inversions.

Marking lights will involve either power from the ground, power from primary FEGs, or power from dedicated RATs.

IFR AWES Window. During IFR Conditions AWES are shielded from vFR traffic.

While most safety considerations tend to restrict AWES operations, there are potential compensating factors. A major opportunity is to fly AWES more freely during IFR conditions when such conditions result in an absence of air traffic (nighttime, low visibility, below IFR altitude minimums, and full ATC determinism.

sUAS Piloting Concern- Site noise can mask the noise of intruding air traffic from a PIC or VO. (An airplane is often heard before seen, helping "sense & avoid".). Distractions and loss of concentration are common risks.

AWES Ground Operations

Preventive Maintenance. Simple preservation operations and replacement of small standard parts. These constant routines are usually supervised or performed by the PIC.

Airspace

14 CFR part 77 Obstruction regs are to apply to early AWES, limiting them to under 2000ft AGL. Unlike fixed obstructions, AWES must coordinate operations with ATC.

Class G Airspace, and its land footprint, is the general realm of AWES R&D and future Operations. FSDOs are the arbiters of allowable experiments, with a decentralized flexibility. AWE R&D can "shop-around" for a "best-fit" FSDO (generally remote low-traffic NAS regions).

Recreational and General Aviation is feeling squeezed from above by expansion of Class B airspace, and from below by man-made obstructions like masts and AWES [EAA]

Future airspace is being defined by NextGen.

NOTAM & COAs allow pioneering AWE R & D to occur. Shielded operations is an option for AWES at suitable sites.

Case Note- Small Airports Hoping to Accommodate AWE R&D

A growing list of small airports seek to host AWE R&D, to replace declining revenue from other activities. Discussions with airport administrators and their stakeholders (aviators, aero clubs, skydivers, etc.) reveal a prevailing conviction that AWE can coexist with general aviation, that the operational issues are manageable. The players are eager to validate the new applications [WOW Italy].

There will be many eager FBOs as word gets out. Those fields are favored that have a combination of good wind, low existing air traffic, and some specialization advantage, like tow-launching, banner-towing, or skydiving operations.

Many airports have large open spaces beside runways, (but away from approaches), suitable for limited low altitude "killable" AWES arrays under the control of the airport administration.

Airports with a crosswind runway have an interesting potential to host crosswind AWE generator vehicles on the idle runway. Operations could switch runways as the wind veers.

Suggestions for AWE R&D operations at small airports

The activity should be considered experimental, and suspended at any sign of trouble.

Only small-scale low-mass low-velocity low-altitude AWE operations are currently suited to existing low-traffic small airport operations. Only low air-traffic remote airports, with full local pilot awareness, are suited for R&D.

AWES altitudes should be as low a 200ft, with high conspicuity (3 mile minimum).

Aeronautics engineers and pilots should prepare or review the AWES design and site plan and help present it for regional FAA FSDO review and approval. Shop around for NAS regions with air low traffic and willing inspectors.

Particular concern must be paid to not crowd airfield approaches and enroach on the standard traffic pattern. Current FAA kite visibility standards are weak and should be exceeded. All local pilots should be fully informed of operations.

AWECS operations must have a Pilot In Command (PIC) (plus often a Visual Observer (VO)) able to quickly douse the kites (kite-killers) at first sign of trouble, especially in case of another aircraft's landing or take-off emergency (FAA Sense and Avoid requirement). The PIC or VO must monitor radio traffic. All incidents and mishaps should be reported and investigated, with solutions identified.

NOTAM can be daily filed (or equivalent airman awareness, like charted obstructions), just as skydiving and hot-air balloon operations do. Shared operations require education, coordinating, and briefing all the conventional users. Small FBOs and remote airspace tend to host an easily-informed close community of users.

Dynamic AWE power loads and surges must be buffered or isolated from airport electrical systems.

ETOPS Model for AWE EndurOps

AWES requires long-term flight persistence. The required endurance is unprecedented, ranging into thousands of hours between inspections and overhauls. A new operational category of EndurOps is proposed, with ETOPS as a model aspirational standard. ETOPS began as a specific standard for long transport flights over water or remote from an emergency landing field.

A similar standard is needed to address intensive field operations of AWES. The rationale is that many technical issues are identical or similar. for aircraft expected to run for long periods unassisted, with aircraft that must not fail over water or far from airports. Many of the standards for redundancy and reliability will apply.

Airframe and engine combined must meet basic ETOPS requirements for type certification. ETOPS operational certification involves special engineering and flight crew procedures on top of normal engineering and flight procedures. Pilots and engineering staff must be ETOPS qualified and trained. Operators with extensive long distance flight experience may be awarded ETOPS operational approval immediately, others must demonstrate ability through a series of ETOPS proving flights. Regulators monitor ETOPS performance of both type certificate holders and affiliate airlines. Any technical incidents during an ETOPS flight must be recorded. From data, the reliability of particular airframe-engine combination is measured and results published. EndurOps will be similarly validated.

Inspections

Current aircraft are constantly preflight inspected by its crew and frequently spot inspected by qualified maintenance. They undergo significant and major inspections on an ongoing basis.

In the absence of standards for extreme high-duty (high flight hours) of infrequently inspected AWES Aircraft, current standards must apply. Exception should only be made case-by-case where risk has been mitigated, for example, remote operations away from populations, with minimal personnel exposure to risk.

Production Approval Holder. A holder of a production certificate (PC), an approved production inspection system (APIS), a parts manufacturer approval (PMA), or a technical standard order (TSO) authorization who controls the design and quality of a product or part thereof.

Designated Engineering Representative (DER). An individual appointed in accordance with § 183.29 who holds an engineering degree or equivalent, possesses technical knowledge and experience, and meets the qualification requirements of this order.

Conformity Inspection of Prototype Products and Related Parts. An inspection to determine the applicant's compliance to 14 CFR part 21,

Certification Procedures for Products and Parts, § 21.33(b) and any other inspections necessary to determine that the prototype products and related parts conform to the proposed design drawings and specifications.

Conformity Inspection of Production Products and Related Parts. An inspection that may be necessary to determine that completed production products and related parts conform to the approved type design and are in a condition for safe operation.

Case Example- Routine, ramp, intermediate, and major checks monitor transport fleets. Routine checks involve dozens of tasks listed by check headings. Constant ramp checks are more thorough every 10 days to 1 month, hanger checks occur every 3 months, interchecks every 15 months, and major checks every 24000 flying hours. Hanger checks put an aircraft out of service for 24 hours, interchecks 10 days, major checks 5 weeks. Source- AZoM.com

Insurability and Legal Liability

As aviation in shared airspace, TA operations must carry Liability Insurance proportional to risk. A wrongful death these days can cost ten million dollars in liability and easily kill a culpable (or related) aviation business that then becomes commercially uninsurable.

AWES insurance is currently unavailable from traditional providers, so an industry supported self-insurance pool may be needed to jumpstart liability coverage availability. Secondary coverage, like Hull Insurance, awaits market maturation. The insurability guaranteed by an excise endowed fund can ensure that a financially weak AWE player in a freak-accident (unpredicted failure-mode) event does not leave victims or families uncompensated.

A path to early insurability will be via the aviation associations, who already offer members group-rate coverage, subject to applicable rules and conditions.

TA Regulatory Compliance

Aviation safety is the professional cost of AWE sharing the sky. No serious AWES player can advance by bucking aviation safety culture. To lead the AWES industry in safety compliance is a clear competitive advantage. Aviation operators are civilly liable to third parties for negligence and recklessness quite apart from what aviation regs say. Criminal law applies to willful law violations or gross negligence resulting in harm to third parties.

DOE/NREL Input

Director Fort Felker's 2010 NREL presentation, Engineering Challenges To Airborne Wind Technology, deserves close study and is an excellent foundation for the AWE Industry to build on. The following are notes and commentary to the work, preparatory to TACO integration. Where Fort's terms are super-specialized or non-standard, they are recast for clarity. Comparison with the original document can sort out which ideas are Fort's, and which are appended.

Fort asserts the well-known attractions of AWE but focuses on the widely overlooked challenges. He consistently emphasizes that all system reliability requirements must be "explicitly defined" and early on warns that aviation "reliability is expensive", which particularly relates to complex aircraft costing roughly "500 dollars a pound". Some way to slash costs close to "five dollars a pound" must be found. The AWES string and rag KIS school seems closest to this high affordability.

Integrated Risk Management is a key part of the general Systems Engineering. A "rigorous risk reduction process" is called for. Fort covers many uncertainties, like who decides to recover after an automated shut-down. The Design Load Case-base to simulate and test must be exhaustive, including common Extreme Events like ECD- extreme coherent wind speed and wind direction change load cases (especially downward and rearward bursts).

Partial Failure Cases include Structural, Electrical, and Control System Faults. Fort cites the structural Engineering Safety Margin of conventional aircraft, but AWES operational extremes may require the higher standards of special utility and aerobatic types. The Design Environment is the chosen operating environment state-space, like if the system is to be operated in specific extreme weather conditions. Many kinds of special factors apply, like operations offshore or around populations.

Life Cycle Cost Modeling is another facet of Systems Engineering. Fort breaks this down as Development Cost, Manufacturing and Deployment Cost, Financing Cost, O&M Cost, Replacement Cost, and Decommissioning Cost. Land Cost should be added; systems with an extravagant land-need per installed-watt are disadvantaged. Design and Verification Standards are carefully considered. Existing standards from wind energy and aviation are proposed for adoption as practical, but specific new "Certification Standards are urgently needed"; they do not yet exist. Due Diligence remains problematic until the new standards are in place. Third Party Validation is the essential finishing step to design verification.

Fort is not alone in predicting that AWES will "grow in size and become more flexible." Larger more flexible systems eventually means soft lattices of large soft (or smaller stick) kites, as the scale limits of single kiteplanes become restrictive.

Comprehensive component and field testing gets the greatest emphasis by Fort. Elsewhere he has opined that ARPA-E should be testing a "balanced portfolio" of AWES contenders. He especially advocates Highly Accelerated Life Tests (HALT). HALT will be the main job of many developer teams, with extended testing undertaken in highly adverse conditions, not just in ideal conditions. Even so, tens of thousands of flight hours are required to fully inform us.

Simulation Tools is another area Fort finds lacking in essential capabilities and validation. Fatigue Analysis over the design life is a requirement.

Aero-Servo-Elastics is a frontier topic- the capacity of a system's own actuation to trigger flutter under specific conditions and the damping required to avoid divergence. Even simulation input data must be validated.

Fort echoes a hard reality, that "development of control systems for aircraft has become a long expensive process." A few standard control methods and issues are listed, but this is a big topic, especially for non-piloted systems. Environmental and Human Impact Assessment is mentioned not so much as daunting than as a necessary task.. Fort repeats calls in open circles for collaboration across the industry to resolve common problems.

Over a year has passed since Fort laid out these challenges. The AWES R&D community is committed to resolve them (AWES Forum). ARPA-E has been formally requested to apply Fort's "DOE/NREL Principles" to MakaniPower's contract testing and analysis work-product.

Every R&D team is advised to follow Fort's admirable template as well.

Engineering Challenges of Airborne Wind Technology (Presentation)
www.nrel.gov/wind/pdfs/49409.pdf

AWES Structural Load-Case Analysis

Large scale tether and membrane AWES have special structural characteristics, and associated operational methods, involving diverse engineering fields.

Ground Anchors are a critical component of many TA classes. Civil engineering and associated soil geology figure in tethered flight regulation.

Load cases with time steps are used in dynamic analysis. Each load case has a set of forces, moments and nodal deflections. In natural frequency (modal) analysis each load case presents a mode shape and frequency. This is highly specialized work in the case of complex systems with stiff composites, but data can also be generated by extended field testing, especially with simple systems.

AWES Service Life

It is generally supposed that stiff composite airframes may someday dominate AWE, Owing to exceptional performance. This can only occur as safety and reliability allows, as the system must be insurable and survive long enough achieve capital pay-back. The current preponderance of fabric-based designs reflects an initial advantage in safety and robustness. Slow low-mass soft-wings can "crash" and recover immediately without "Hull Loss".

Properly designed rigid airframes do have fatigue issues, particularly in high G aerobatic and hard landing cycling, but should give a decade of more of service life. Soft wing skins will not last so long, although the load-path structure life may rival solid wing lifetimes, with skin renewed periodically. Fabric covered aircraft do remain airworthy for up to a decade or so, even tied-down outdoors.

A recent estimate of kite fabric life comes from one of kiting's greatest engineer, Peter Lynn (Sr.), who had initially thought that rigid AWE wings were advantaged in service life until he bench and flight tested Dominco Goo's paraglider and kite fabric after 14 months exposure to New Zealand UV and gales, and found it still fit for use.

This is consistent with KiteLab's independent study; the secret is polyurethane sizing with anti-UV additive. Kite fabric is paper-thin, but a composite wing is like a five-hundred page book. Hybrid schemes above allow composite wings in the high-speed crosswind role (though "racing parafoils" might be good enough). Existing airplane fabric uses aluminum or titanium based pigment for UV resistance.

Ground facilities can be essential permanent, with anchors, winches, generators, and so forth, lasting many decades in service. Ground-based equipment is built heavier, and is cheaper and easier to maintain. Issues like actuation saturation v. flying weight is less of a concern.

Environmental Impacts of AWES

NIMBY Noise and Visual Issues

Sound emanating from above travels farther with less attenuation than surface noise. Atmospheric layers can channel sound long distances. Acoustic interference and lensing effects often cause sound peaks to occur remote from a source.

AWES turbines on resonant composite wings tend to be noisy (Makani Power), sounding like an engine or high-speed machinery. Slower large scale oscillating wings can create "booming" and infrasound noise pollution. This noise can range from "washing machine" to "ocean wave". Noise issues with AWE can be judged by extending existing test point standards of AWEA.

Visual Impacts of AWES will be mixed. Opinion will vary over esthetics and there will be specific concerns, such as distraction to motorists. In general, high altitude operations will have a reduced direct visual impact, but over a wider area.

Wake Effect CAT

Wake turbulence in the form of compact wing-tip vortices will extend for a considerable distance downwind from individual large high-performance tethered wings. Larger less concentrated "mountain wave" turbulence will be caused by aggregated farms. The airspace and aerodynamic efficiency of a Kite Farm is limited by internal wake effects; farm scaling is sensitive to wake issues.

Long-term Megascale Impacts

Weather and Climate Effects

Just as condensation trails and CO2 emissions by existing aviation are increasingly considered environmentally significant, it will be recognized that large-scale AWES operations will have consequential atmospheric impacts, like rain shadows and peaks around large kite farms much as terrain causes.

Early Kite Farms will cause only micrometeorological effects, but long term meso- and mega-scale geoengineering impacts may range from catastrophic to existing ecosystems, to geoengineered mitigation of climate change or natural disasters[KLG].

Wildlife Issues

Birds (and bats*) have a primordial right to airspace, but can present a hazard to human aviation and are themselves at risk by activities like conventional wind power generation, night lit towers, etc.. The problems are increasingly well known and mitigation is an ongoing process. AWES design can mostly build on existing bird management practices, adding new protocols as needed.
Migratory species in transit are most vulnerable to disturbances, but follow fairly predictable seasonal patterns, helping risk mitigation. Conventional windfarms can cause wholesale slaughter of flocks, so regulations are emerging to curb seasonal risk. Sense-and-Avoid capability of AWE systems might serve to give clearance to migrating formations. Sense-and-Warn (bird scaring) might also work, but is an open study.

The presence of endangered bird species or high bird populations raise the urgency of bird issues. Nesting birds can be stressed by looming kites, acting out predator response behaviors. In extreme cases birds will abandon active nests, but in other cases birds adapt to kites and even seem to exploit some operations as defensive cover. Generally year-around birds exposed to kite operations adapt well, fully habituating, showing no stress response. Birds that first encounter kites can react by fight-or-flight response. Hawk kites scare birds away and might be a useful management tool, but birds are intelligent and often learn to ignore an empty threat. Young birds can act quite different to the same cues than their more experienced parents. Flying birds are most common near the surface and become rare with altitude, with few exceptions (like migrating snow geese over high mountains). AWE at higher altitude therefore seems more bird friendly that wind towers. A tendency exists for many birds to shun a looming flying object, a prey predation response.

Its possible that any intensive wind energy operations change bird species distribution of their area. Towers are known useful to raptors, and turbine killed birds can attract scavengers. AWE has the potential to reduce such changes compared to tower farms. AWECS and other aerial structure should be minimally visible to birds even at night, by white markings. Black or dark red markings by day usually give the farthest warning to air traffic for easy avoidance.

Conspicuity can reduce or increase air hazards to birds. Nav lights intended to warn pilots of night proximity can confuse migrators.

Turbines that make noise and have red painted tips to delineate the disk area better warn birds of an impact hazard. Fast-moving lines are a special hazard, potentially acting as a saw. Painting alternate black (or red) and white marking on moving line could help by making the motion visible. Fog has disoriented migrating birds, which sometimes cue on artificial lights, like radio mast warning lights.

A proposed farm method is to radar-detect airtraffic and only then activate warning signals. Another idea is to create clear migration corridors, well chosen gaps in the wind farm pattern, for birds to follow. The design of an AWECS can range from benign to deadly to birds. Where bird issues are most sensitive, the slower, softer, more visible systems are favored. Although direct data is scant, its probable that fast moving kiteplanes flying aerobatically constitute the same sort of hazard to birds as large conventional turbines. Many birds seem to have a hard time detecting or understanding the threat of a large fast-moving object on a highly curved trajectory, but do better avoiding an aircraft on a set course. Birds easily see and avoid large slow moving tethers and kites, with no known mortality factor. Birds often do not see the fine lines on toy kites and collide with them, usually with no bad effect, although a small potential for injury exists. Classic kiting is bird friendly, with the exception of fighter kites with cutting line. Some South Asian traditions even regulate the kite-fighting season based on bird presence.

Fallen line must always be collected to avoid snaring wildlife. The risks are two-way. A bird strike can bring down almost any airplane by varied damage. Engines can be damaged enough to stop. Control surfaces, pitot tubes, cameras, antennas, etc. can be made inoperable. A kiteplane is subject to bird-strike risk, it can be blinded, brought down or breakaway, creating risk off-field.

Bird study is a part of AWE site assessment. Baseline bird presence should be determined before a kite farm is established and bird presence tracked for ongoing impact detection and mitigation. Qualified independent biologists should be relied on to develop flexible management plans to meet high standards. AWE and birds will seemingly coexist well, but its up to designers, planners, and operators to make sure adverse impacts are minimal.

*Bats are presumed to resemble birds in their general relation to AWE, but with a more nocturnal presence.

HazMat

Wind power has reduced issues with pollution. Modest concerns include toxic materials (E-Waste), operations like airframe washing, and improper system decommissioning. Decommissioning should be by design, with maximal recycling. Soft-kites with shorter service live should be fully recyclable.

A crash of a complex modern aircraft system can leave a large debris field requiring a meticulous clean-up to appropriate environmental standards. Ablation of fabric particles from aloft may be an issue with poorly formulated kite materials in high-duty service. Equipment fire can have high toxicity to fire fighters. Mass manufacturing should ideally be low impact.

Nextgen Integration

Iterative-spiral toward NextGen-

Input from all TA stakeholders and review by NextGen planners.

Addressing of Concerns. Identification of Solutions.

Technical Validation by Field-Testing.

Sign-off by stakeholders.

Adoption into NextGen ConOps.

AWES NextGen standards

NextGen Network Integration- Positioning, Navigation, Timing (PNT) Services; RealTime Community Of Interest (COI) utility; Layered Adaptive Security (LAS)-

TAO will be a fully integrated sector. PIC comm linked.
Service Performance-Based Operations

Load On-Demand; it will be the goal of the AWECS to respond to load demand with LAS. Weather-Based Decision-Making- An Essential TAO function.

Trajectory-Based Operations (TBO)- Variable geometry kitefarm operations will be certified.

Super-Density Operations (SDO)- Airspace will be treated as a limited resource best maximized by AWE SDO well separated from air traffic.

Autonomous Flight under NextGen

Supervisory Override of Semi-Automated Flight is a bridge technology
NextGen's Moving Constrained Airspace is a capability needed for Tethered Free-Flight development EVFR rules for relaxed visibility will widen the TA flight envelope & be a bridge to Autonomous IFR.
NASA-FAA Research Transition Teams - JPDO Presentation

Federal Governance Issues

TA as whole is a new basis for an expanded sustainable aviation. AWE is potentially a world revolution in abundant renewable energy. The US FAA has a key global leadership role as the de-facto international aviation standard-setting body. The DOE also has a global leadership opportunity in AWES. Policy makers can maximise the opportunity by strong prompt positive action. The concern is sometimes heard that the FAA and/or DOE will play an obstructionist role in AWE development, but this is contrary to the legal mandates on these US Agencies.

NREL Director, Fort Felker, has called for the Federal Government to develop a "balanced portfolio" of AWE R&D support.

A hot-button AWES issue identified is the concept of airspace privatization. There seems to be a strong consensus in aviation circles to maintain airspace as a shared commons.

Currently Restricted Airspace, especially if underutilized, should be evaluated for AWES High Altitude R&D availability.

Mass job creation is a potential policy outcome of supporting AWES development. AWES operations are predicted to require workers at about the intensity of nuclear power plants (~300 workers per gigawatt).

AWE Excise Taxes and User Fees

AWE taps airspace as a source of vast energy. Energy markets pay excise taxes; 5% of a producer's selling price is typical. Unlike non-renewable energy sources, which eventually run out, renewables can generate excise revenue in perpetuity. Barriers to broad AWE societal stakeholder acceptance, like NIMBY (not-in-my-back-yard) forces, will melt before a rich new tax base that more than offsets any negatives. The average citizen who does not fly or own aircraft still shares a birthright to the airspace commons. An equitable AWE Excise Tax can make a huge contribution to basic social welfare & a new era of sustainable prosperity for all.

Airspace access by international legal tradition is a Public Commons based on the doctrine of Freedom-of-the-Seas. There is stiff resistance by existing aviation stakeholders to privatization of NAS as some venture-capital AWE stakeholders propose. Utility-scale AWE operations can contribute to shared airspace by paying Excise Taxes on energy extracted & maybe even special Airspace User Fees.

Airspace User Fees are an unpopular idea to aviation practitioners. The AWE industry can thus earn aviation stakeholder acceptance by subsidizing common airspace infrastructure benefiting all. AWE tax revenue can offset existing FAA costs, relieving the overall Federal budget, pay for NextGen infrastructure, guarantee liability performance, and fund publicly-shared AWE R & D. The early industry needs a phase-in period for taxes, to promote initial risk investment and growth. As a mature AWE revenue-base develops, and airspace becomes widely impacted, a new excise tax base can be established. Small-scale personal AWE operating at low altitudes would be exempted commercial taxes.

Standards Enforcement

Due to wide publicity, many naive unqualified aspirants are attracted to AWE. TACO recommends a forebearant yet vigilant attitude on the part of authorities. Aspirants should be guided into appropriate aviation associations, and only be sanctioned in cases of gross recklessness.

In return, aviation associations must bear a responsibility to enforce and maintain the highest safety and legal standards.

K-Prize Standards

ARPA-E has announced a possible prize competition for AWE (aka "K-Prize"). AWEIA's advisory board holds that such a contest should apply key standards, including FAI Sporting Code rules, US FARs, and basic insurability, in order to ensure the safest possible event. Additionally, engineering data should result, consistent with needs identified by Fort Felker (DOE/NREL).

Land-Use Issues

Concerns include land-use loss from "no go" safety zones, and sprawl, in the case of early sparse AWES design configurations. Designs must be as inherently safe and and use as little and and airspace as possible.

Opportunities exist for synergistic compatible use. A kite-farm might make windpower over a biofuel crop like hay or a methane-producing landfill unsuited to other reuses. Degraded land might slowly self-restore under low-impact AWES.

The ultimate outcome will be safe practical low-impact operations over dense populations.

Case Analysis- Land and Airspace Sprawl

In many cases a single-line AWES on a full-scope field will be acceptable, but for large-scale power, large farms will be required, and maximal utilization of scarce land and airspace will be essential. In the absence of direct experience, analytical geometric thought experiments offer some predictions. The following "gedanken" case is based on a Makani Power M-1 wing concept "fly-off" against a KiteLab Group dense array concept:

Suppose a large enough fleet of airliner-sized single-line AWES kiteplanes, each rated at a couple of megawatts, to power a major city of 1-5 gigawatts load. The city would need roughly one to five thousand large complex aircraft each occupying about a half square mile of "no-go" space, for a sprawling land footprint of 500-2500 square miles. This many aircraft would make that city a host for aviation activity two to six times more intense than Heathrow, the world's current busiest airport.

A 50sq m reference wing occupies a crosswind-projected reserved airspace of 500,000sq m (1km x 1/2km). This is only a 1/10,000 "solidity" factor, so its not surprising the little wing cannot sweep up very much of the energy flowing thru its space.

A ballpark estimate is that the best soft wings are roughly 10 times the area of rigid wings by equivalent power (especially by leaving generators, conductors, etc. on the ground). Dense cross-linked arrays may be able to do about 100 times better, in power by land or airspace usage, than single tether electric kiteplanes.

KiteLab suggests a handy operational scale for soft array wings of about 100sq m; five such soft wings roughly match a high L/D 50 sq m wing. One hundred such wings can be arched together across the same airspace, with plenty of spacing to avoid interference drag. Each of these wings can lift a high L/D airfoil of 50sqm to be held semi-captive in the latticework, looping crosswind in close proximity to its neighbors, but constrained by the matrix from collisions.

So now the array has airliner-equivalent wings in passively constrained sweeping unencumbered by generators, actuators, battery back-ups, avionics, etc.. Cleaner and lighter, they develop more power.

The dense array concept agrees with Prof. John Dabiri's findings (Biolocomotion Lab, Caltech) where a ten-fold increase in wind power extraction was demonstrated, by unit land area, by crowding many more slower turbines in the same spac, as compared with conventional wind farms. In the case of AWE, the added vertical dimension exponentially allows another tenfold gain in calculated potential. Thus dense cross-linked arrays seem able to do about 100 times better, in power by land or airspace usage, than single tether electric kiteplanes. The 15,000sq m projected airspace area then has a reasonable solidity of about 1/30. A large city now only needs 5-25sq miles of land footprint with dense kite arrays, 1/100th of the single-line AWES reference model.

The challenges to the dense hybrid array approach are mostly operational, its truly heroic sailing in the sky. Kites are handled by simple traditional means of furling lines, sleeves, and packs. The entire array is piloted as one "metakite/megakite" from powerful ground winches to drive the largest class of generators. Large machinery runs many decades with just routine maintenance. This scheme creates many kite-flying jobs. A labor force comparable to nuclear power (with its elaborate safety and security needs) is needed, of about one worker per two or three MW. Jobs are an urgent societal need, like clean energy, for a win-win dynamic. A golden age of sky sailing can be a bridge to eventual fusion or space-based solar power.

Low-tech arrays do not require waiting decades or spending billions for complex aerospace perfection.

Single-line AWES geometry makes scant use of the total energy in its required airspace. In some prototype videos the kiteplane is so hard to see, lost in a wide loop, that presenters resort to a laser-pointer to pick it out. Over 99% of the calculated energy in the required airspace goes untapped by the single line approach.

The land footprint of single line systems also sprawling. Some proposed single-megawatt AWECS will require a field about 4000ft wide! Due to safety issues of high-mass high-speed aircraft, the field and airspace must be kept clear of populations or outside air traffic. An array interconnect network of roads and buried cables for this sort of AWECS is similarly extensive and expensive. Tens of square miles would be needed to serve a city. Such schemes face high barriers in shared air and land use markets.

OffShore AWES

Sea-based AWES have specific attractions, including less impact on the NAS. But the sea is a hostile environment, with its own daunting engineering challenges.

Boats are in many ways ideally flexible for "kite-sailing" operations, and there will be lots of shared functionality with land operations. Just as seaplanes are a major branch of aviation, TA will have a strong amphibious sector.

Gigawatt Scale AWES Concepts

TUDelft, with its Laddermill concepts and Kitegen its Carousel, have many years of study in gigawatt-scale AWES concepts. KiteLab Group proposes megascale AWES with many anchors and fully cross-linked formations of kites. These concepts offer economy-of-scale in using the largest ground-based generators. Some legacy powerplants will even be suited fro retrofitting as kite-hybrids.

Decommissioned nuke plants could be reworked as AWES sites, with the restricted airspace used as the new generation basis.

Dr. Fagiano {Turin Polytechnic] has begun to study AWES airspace efficiency. All teams and investigators should carefully examine this issue. The winners in the AWE engineering race will be determined by a handful of critical design issues like safety and maximal space use.

AWES Documentation

FAR documentation norms cover AWES UAS needs. A Special Airworthiness Certificate in the Experimental Category is the certification currently available to civil operators of UAS.

Existing aircraft certifications can be partially applied in cases of repurposing as AWES devices.

Part 77 certification requirements now apply to ongoing AWES Operations.

AIM

AIM is the FAA's official guide to basic flight information and ATC procedures. It covers NAS, pilot human factors, flight safety, ATC glossary, and safety, accident, and hazard reporting info. AIM re-states and expands FARs in ten chapters:
It is proposed that chapters 3 and 5 contain specific amendments regarding AWE operations, and that eventually a chapter be included defining general TA or specific AWES operations, as the category matures.

AIM 3-4-6. Alert areas are depicted on aeronautical charts to inform nonparticipating pilots of areas that may contain a high volume of pilot training or unusual type of aerial activity, to particularly alert pilots flying in these areas. All activity within an alert area shall be conducted in accordance with CFRs, without waiver, and pilots of participating aircraft as well as pilots transiting the area shall be equally responsible for collision avoidance.

AIM 3-4-7. Controlled Firing Areas CFAs contain activities which, if not conducted in a controlled environment, could be hazardous to nonparticipating aircraft. The distinguishing feature of the CFA, as compared to other special use airspace, is that activities are suspended immediately when spotter aircraft, radar, or ground lookout (PIC/VO) indicate an aircraft might be approaching the area. There is no need to chart CFAs as they do not cause a nonparticipating aircraft to change flight path.

A statement of compliance (SOC) is a signed statement made by the AWES manufacturer stating that the unmanned aircraft system (specific by serial number) was designed, manufactured to applicable consensus standards, and is supported by monitoring and correction of safety-of-flight within a continued airworthiness system.

Configuration, Maintenance, and Procedures (CMP) Document is an approval by the FAA with minimum configuration, operating, and maintenance requirements, hardware life-limits. The Master Minimum Equipment List (MMEL) constraints necessary for an aircraft system to meet ETOPS level design approval requirements.

FAA certification offices provide airworthiness certification or related approval: Manufacturing Inspection District Office (MIDO), Manufacturing Inspection Satellite Office (MISO), Flight Standards District Office (FSDO), International Field Office (IFO), Certificate Management Office (CMO), or CertificateManagement Unit (CMU).

Production Approval Holder. A holder of a production certificate (PC), an approved production inspection system (APIS), a parts manufacturer approval (PMA), or a technical standard order (TSO) authorization who controls the design and quality of a product or part thereof.

Prototype and Production Manufacturing Standards
Conformity Inspection of Prototype Products and Related Parts. An inspection to determine the applicant’s compliance to 14 CFR part 21, Certification Procedures for Products and Parts, § 21.33(b) and any other inspections necessary to determine that the prototype products and related parts conform to the proposed design drawings and specifications.
Conformity Inspection of Production Products and Related Parts. An inspection that may be necessary to determine that completed production products and related parts conform to the approved type design and are in a condition for safe operation.

Designated Airworthiness Representative (DAR) is a maintenance of manufacturing worker appointed in accordance with § 183.33, who holds a mechanic's certificate with an airframe and powerplant (A&P) rating under 14 CFR part 65, Certification: Airmen Other Than Flight Crew-members, or a person who holds a repairman certificate and is employed at a repair station certificated under 14 CFR part 145, Repair Stations, and who meets qualification requirements of this order. In manufacturing a DAR is appointed in accordance with § 183.33, who must possesses specific aeronautical knowledge and experience, and meets the qualification requirements of the order.

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Thanks to the many individuals who helped, and to the many to come, as future versions evolve. It is hoped TACO saves lives while accelerating progress in AWE.

For those seeking a fuller knowledge of AWE, Joe Faust maintains comprehensive archives and links at-

www.energykitesystems.net

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