



**SOCIETY OF ALLIED
WEIGHT ENGINEERS, INC.**

*Aerospace • Marine • Offshore •
Land Vehicle • Allied Industries*

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2020 SAWE MPE CERTIFICATION OUTLINE OF REQUIREMENTS

Prepared by
MPE Certification "Technical Team"
for
Society of Allied Weight Engineers, Inc.
(SAWE, www.sawe.org)



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1 Introduction

1.1 Overview

This document provides a draft outline of the proficiency requirements for achieving each level of SAWE Mass Properties Engineering (MPE) Certification. This outline is designed as an aid in developing the appropriate training classes and exams to ensure that the candidate is qualified to receive the honors, rights and privileges associated with each level of MPE credentials. Questions regarding this document should be addressed to Andy4Schuster@gmail.com.

1.2 Purpose

These requirement will be used by the authors and the Industry Committee that they represent, to define the currently available and required reference documents and training materials. The difference between the available and required materials is a “gap” that will need to be filled with new materials.

1.3 Current Overall Process

This committee completes steps 1 and 6. Steps 2-5 are done by each Industry Committee.

1. Define requirements for a level of MPE certification, starting with the lowest (AMPE)
2. Determine all the references for the candidate to review and understand before being certified
3. Determine how that reference material should or could be delivered to the candidate. (e.g. by online class, face to face class, back ground reading, workbook, etc)
4. Determine whether the current training materials adequately address the requirements
5. Create a list of reference and training materials that need to be developed.
6. Add findings to a summary report
7. Return to step 1 for the next level MPE certification
8. Present summary report to the project management team.

1.4 Terms & Abbreviations

Item	Description
AA	Airline Affairs Industry Committee
Airline Affairs	is also known as “Commercial Aircraft” or “Non-Military Aircraft”
AMPE	Associate Mass Properties Engineer see section 2 for a definition
ANSI	American National Standards Institute
ANSI-CAP	American National Standards Institute – Certification Accreditation Program
BE	Bachelor of Engineering
BS	Bachelor of Science
CoG, CG	Center of Gravity
Cross Industry	SAWE RPs that cover fundamental MPE principals, practices or

Item	Description
	methods that are applicable to all industries
CX	Cross Industry Committee
EMPE	Expert Mass Properties Engineer
FBS	Functional Work Breakdown Structure, for grouping MPs by system or functionality (landing, weapons, fuel etc)
Gap	The difference between available and required materials. The gap must be closed by creating new materials for the program to move forward.
Ground Vehicles	Trucks, cars, tractors, tanks, rovers, trains, trams, buses, mopeds, motorcycles, etc



Item	Description
GV	Ground Vehicle Industry Committee
HazId	Hazard identification study for a new or design for purpose project
HazOp	A set of operation instructions to assure accidents identified in the HazId are mitigated or avoided or addressed.
Hr or hr	Hour
IMP	Interface Management Plan
Industry Committee	Are the SAWE Standards and Practices committees that meet at the International Conference including Marine, Military Aircraft, Ground Vehicle, Offshore, Missile & Space System, Airline Affairs and Cross Industry.
M	Marine Industry Committee
MAC	Military Aircraft Industry Committee
Marine	Government owned or purchased or chartered combatant and cargo ships.
Military Aircraft	Government owned or purchased fixed wing, rotary, drones, cargo aircraft. May include bombs too?
Missile and Space systems	Launch vehicles, rockets, satellites, space stations, lunar or mars ground based systems (rovers, habitats etc)
MP	Mass Properties – the discipline or the attributes (weight, cog, inertia, volume etc)
MPCP	Mass Properties Control Plan
MPE (depends on context)	Mass Properties Engineer – person engaged in Mass Properties Engineering activities Mass Properties Engineering – all actions and skills needed to assure the final product is within mass properties limits Or depending on context Mass Properties Engineer

Item	Description
MSS	Missile & Space Systems Industry Committee
OBS	Organizational Work Breakdown Structure, for grouping MPs. (by subcontractor, department, discipline etc.)
Offshore	Boats, floating production units, mobile drilling units, gravity base structures, submersibles etc use to produce oil, gas, wind power, fisheries etc that operate in lakes, rivers, seas and oceans
PMPE	Professional Mass Properties Engineer
References	For this project includes: SAWE technical papers, RPs, textbooks, guidelines, and handbook.
RP	SAWE Recommended Practices The MPE RPs for specific industries included: A7 for Military Aircraft G1 for Ground Vehicles M1 for Marine Vehicles A-3 for Missiles and Spacecraft
SEMP	Systems Engineering Management Plan
STEM	Science Technology Engineering and Mathematic (degree or programs)
Ton	Unit of mass typically 2000 pounds, unless specified differently
Training Materials	For this project includes: slides, syllabus, instructor notes, exercises, class test, hardware (e.g. for weighing an aircraft)
WBS	Work Breakdown Structure, for grouping MPs. This can be a generic or specific term. OBS and FBS are types of generic WBSs.
WCP	Weight Control Plan, similar to MPCP, for the marine and offshore industries, as used in this document



2 Certification Levels Summary

The following table provides an initial plan for three levels of MPE certification.

The levels are ONLY intended as a Work Breakdown System to identify all the requirements so that the “gaps” in references and training materials, can be identified. The final levels, divisions of knowledge, experience etc as well as the titles will be defined by the management team and approved by the SAWE BoD.

The levels as shown below the Associate MPE (AMPE) level is a cross industry certification designed to ensure the candidate has a basic set of knowledge and skills to effectively support their projects in the area of mass properties control across all industries. The next two higher levels of certification, PMPE (Professional MPE) and EMPE (Expert MPE), ensure industry specific proficiency.

Airline Affairs	Ground Vehicles	Marine	Military Aircraft	Missile & Space	Offshore	Prerequisite
Expert (EMPE-AA)	Expert (EMPE-GV)	Expert (EMPE-M)	Expert (EMPE-MAC)	Expert (EMPE-MSS)	Expert (EMPE-O)	PMPE +10 yrs Total Experience
Professional (PMPE-AA)	Professional (PMPE-GV)	Professional (PMPE-M)	Professional (PMPE-MAC)	Professional (PMPE-MSS)	Professional (PMPE-O)	AMPE + 5 yrs Total Experience
Associate (AMPE) - Based on Cross Industry RPs						2-5 yrs Experience

Additional Prerequisites are defined in Section 3 and 4.



3 Outline of Requirements by level of Certification

3.1 Associate Mass Properties Engineer (AMPE)

As previously mentioned, the AMPE level of certification is **not industry specific**, but rather focused on the common and shared knowledge of MPE. The proficiency requirements are defined below.

Associate MPE Level Requirements:

- Minimum Experience:
 - Bachelor's Degree in a science, technology, engineering or mathematics field of study, and 2 years of MPE experience. **OR**
 - 5 years of applicable MPE related experience.
- Current SAWE member.
- Successful completion of AMPE exam showing proficiency in the following skills:
 - Ability to calculate volume, mass, center of gravity, moments of inertia and products of inertia for an object and/or a collection of objects using material density and fundamental shape and summation equations.
 - Experience calculating mass properties using 3D CAD tools (e.g. CATIA, NX, and/or other)
 - Knowledge of mass properties measurement concepts and techniques.
 - Basic understanding of strength of materials, stress, strain and loads.
 - Basic knowledge of fluid mechanics and buoyancy principles.
 - Basic understanding of subsystem design processes (e.g. structure, propulsion, power, electronics, wiring, controls, etc.)
 - Knowledge of mass properties control methods including risk management.

3.2 Professional Mass Properties Engineer (PMPE)

As previously mentioned, the PMPE level of certification is **industry specific**, and the proficiency requirements are defined by each SAWE industry committee.

Professional MPE Level Requirements:

- AMPE level certification
- 5 years of total MPE experience.
- Current SAWE member.
- Successful completion of PMPE exam showing proficiency in the following skills:
 - To be defined by each SAWE industry committee.

3.3 Expert Mass Properties Engineer (EMPE)

As previously mentioned, the EMPE level of certification is **industry specific**, and the proficiency requirements are defined by each SAWE industry committee.

Expert MPE Level Requirements:

- PMPE level certification.
- 10 years of total MPE experience.
- Current SAWE member.
- Successful completion of EMPE exam showing proficiency in the following skills:



- To be defined by each SAWE industry committee.

3.4 General Notes for Sections 4 & 5

- Unless stated otherwise, all requirements assume the lower level plus. So an expert must meet the requirements of an associate and Professional MPE.
- Skip Levels - MPEs with the requisite experience may bypass the Associate and Professional levels if they can pass all the tests to become an Expert.
- Multiple Industry Expert MPE – EMPE may qualify for a second or third industry by taking the industry exam and meeting the required project experience.
- Technical Paper - To write and present a peer reviewed SAWE paper at a SAWE regional or annual conference on a topic suggested by the VP Technical Director or VP Standards and Practices, author a working draft of an RP, or chapters in a textbook.
- MP Fundamentals – includes are the content in the Cross Industry RPs - *Risk Management, Metrics, Economics, Baseline Control, Program Requirements, Optimization, Estimating, Calculating Weighing, Reporting, In-Service, Data Transfer*
- The requirements are broken into two sets with the following high level breakdown:
 - Cross Industry – All Applicants
 - (1) Experience
 - (2) Safety
 - (3) leadership
 - (4) MPE fundamentals
 - (5) Engineering Knowledge
 - (6) Process
 - (7) Software
 - (99) Miscellaneous (which needs to be refiled in another category)
 - Industry Specific - By Standards and Practices Industry Committee
 - Commercial Aircraft or Airline Affairs Industry Committee
 - Ground Vehicle
 - Marine
 - Military Aircraft
 - Missile and Space Systems
 - Offshore



4 Cross Industry – All Applicants - Requirements

Item	Title author ¹	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
1.00	Experience			
1.10	Experience - Work	<ul style="list-style-type: none"> • Entry level in industry (either) <ul style="list-style-type: none"> ○ 5 years of applicable MPE related experience. ○ 2 years of applicable MPE related and completion of a BS/BE STEM degree • Working in a MPE group • Use of CAD tools, hand calculations and other computer tools to calculate MP 	<ul style="list-style-type: none"> • 5 years of total MPE experience • Leading a project during one or more phases • Checking work of associates • Can qualify for a second industry certification by taking the training and passing the industry specific exam. 	<ul style="list-style-type: none"> • 10 years of total MPE experience • 3 years in at least one industry
1.11	Experience – Project	One Project	2 projects or major phases	4 projects or 4 phases on 2 different projects
1.20	Pre Requisite certification	none	Hold a AMPE certification for 1 year	Hold a PMPE certification for 1 year or AMPE for 3 yrs (but must take both exams)
1.30	Industry Specific	none	General or all industries Or specific to an industry	Specific to industry
1.40	SAWE Membership	Current	3 yrs	5 yrs continuous
1.50	Formal Training			
1.51	On-Line Classes	30 hr	30 Hr or more	30 hr or more per industry
1.52	In person Classes	Total of 4 hr at a regional	Total of 8 hrs at regional or international conference of which 4 hrs at a regional or international conference after qualifying as a AMPE.	Total of 16 hours of which 8 hrs at a regional or international conference after qualifying as a PMPE.
1.60	Exam			
1.61	No of Questions	Complete (100 multiple choice)	Complete (200 multiple choice)	Complete (50 multiple choice)
1.62	Language	In American English only	In American English only	In American English only
1.63	Available	In all countries (e.g Europe, Brazil, China, India, Malaysia, Korea, Kuwait, etc)	In all countries (e.g Europe, Brazil, China, India, Malaysia, Korea, Kuwait, etc)	In all countries (e.g Europe, Brazil, China, India, Malaysia, Korea, Kuwait, etc)
1.70	Sponsor/mentor	A PMPE in the organization or SAWE assigned	A EMPE in the organization or SAWE	Another EMPE

¹ unattributed authorship, means written by Andy Schuster,



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Item	Title author ¹	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
1.80	Contribution to Profession	None	1 technical paper	<ul style="list-style-type: none"> • 2 more technical papers • One paper should expand the knowledge base of MPE. • Mentor an AMPE
2.00	Safety	Know safety limits (weight & CoG) Examples in the Industry Specific Requirements	Set and enforce limits (project or product line) Sign off on authorizations (Form F) Example in the Industry Specific Requirements	Derive or establish limits and policies Offshore- with HazID and HazOP analysis Examples in the Industry Specific Requirements
3.00	Leadership & Interpersonal Skills Update with pats details	Work with other disciplines to determine current data Prepare and organize a meeting	One on One skill <ul style="list-style-type: none"> • How to interview a Discipline Lead • How to prepare chair and close out a meeting • How to report status to management • How to motivate, mentor, council staff • How to check work without redoing it. 	Lead a group <ul style="list-style-type: none"> • Chair teams to control, optimize MPs • Department leadership of a MPE and others • Industry committee co-chair • SAWE officer leadership • Community committee leadership
4.00	MPE Fundamentals		•	•
4.1	Design Development	Familiarity with the Cross Industry RPs to be able to complete actions, or calculations or fill in equation as defined in the project plan or company procedures or RPs	<ul style="list-style-type: none"> • Write a MPC or WCP plan based on customer requirements. • For estimating be able to derive parametric equations • Derive a Bill of Materials from a parametric weight estimate (e.g. long lead items) • Be able to check work of others 	<ul style="list-style-type: none"> • Define plan requirements • Maintain overall quality control • Approve work of others
4.2.1	Validation	Weight calcs Estimates	<ul style="list-style-type: none"> • checking • model validation 	<ul style="list-style-type: none"> • approval
4.2.2	Validation By Andy Walker	<ul style="list-style-type: none"> • Basic concept knowledge of techniques to validate Mass Prop estimation, calculation, and measurement methods 	<ul style="list-style-type: none"> • Calibrate high-level methods for estimation, calculation, and measurement with historical and/or higher-fidelity data • Establish/ Document calibration factors for validated models • Identify reasons why current estimate diverges from validated design metrics (e.g. % Body-Length CG, Weight per Measured Area, Group Weights as % of Gross Weight, Analytical Mass Distribution) 	<ul style="list-style-type: none"> • Establish reasonability checks for model validation • Able to ensure/ certify that estimation models have enough validation to meet quality control requirements



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Item	Title author ¹	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
4.2.3	Validation By Jeff Vaughn	Determine the assigned target weight for the item and system. <ul style="list-style-type: none"> • A summary of target weight plus contingency will ensure a system will meet performance requirements. The value that the item/system is expected to weigh should be available from existing design and specification documents • 	Derive target weights for the items and the system to meet customer system requirements. <ul style="list-style-type: none"> ○ Typically, a system target weight is a derived requirement from performance capability of a system. To meet the system target weight, target weights for sub-systems, assemblies, and parts are determined. ○ A method for estimating is to use parametrics developed from similar systems and adjusted for unique system requirements. ○ A more mature method is to perform a "bottoms up review" based on preliminary drawings with updates as the drawings mature. ○ Each method carries a measure of uncertainty. A system target weight will be assigned a contingency to cover this uncertainty, growth margin (both planned and unplanned) and expected manufacturing variation. 	Weight As an Independent Variable (WAIV). <ul style="list-style-type: none"> ○ Ensure that weight-engineering processes are balanced for cost, schedule and performance both internally and externally. ○ System weight is directly related to cost. Ensure that weight estimates derived from requirements are in line with the cost estimates for a system. ○ Negotiation with a customer is critical to ensure the right mixture of requirements, oversight, and reporting will result in program success. Develop Standard Practices. <ul style="list-style-type: none"> ○ Develop tools and standards to be used by others to ensure weight will achieve customer requirements. These include Mass Properties Control Management Plan (MPCMP), Industry Standards, Recommend Practices, Internal Standards, and Operational Procedures, Contingency and Uncertainty Factors.
4.3	Verification by Bell Lee	Able to follow procedures to weigh an item. <ul style="list-style-type: none"> • Basic knowledge of techniques for weighing, CG and inertia measurement • Understand required data collection from testing • Perform verification of other Mass Properties by using analysis of test data • Perform uncertainty analysis 	<ul style="list-style-type: none"> • Write weighing procedure • Define verification requirement • Develop verification plan • Develop test procedure • Knowledge of subcontract development (SOW) and coordination to define required EIDP • Develop parametric tools using verification data • Mentor junior engineers on verification methodology and processes 	define Weighing plan for a project <ul style="list-style-type: none"> ○ Experience with test equipment procurement process ○ Solid understanding of requirement driver to determine verification by analysis vs. testing ○ Experience in proposal work in relation to cost estimation in verification/validation



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Item	Title author ¹	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
4.4.1	MP Measurement SAWE Paper 2444	Steps in Making MP Measurements Establish a frame of reference Choosing a fixture Methods used to measure CG Location MOI Measurement Considerations in choosing a MP Instrument Weight Measurement Proper reporting of MP Measurement (ARS)		I.
4.4.2	MP Measurement By Haley Roalson & Damian Yanez. SAWE Paper 2444 <i>The purpose of these learning objectives is to ensure that the Mass Properties Engineer (MPE) has the appropriate level of knowledge in mass properties measurement techniques to choose a valid method, properly perform or supervise these operations/tests, and process and report the results to a customer.</i>	I. Weight Measurement <ol style="list-style-type: none"> a. Understand the difference between mass and weight and know the basic units of measurement for both. b. Know the mass/weight measurement instruments and the advantages and disadvantages of these instruments. c. Know the factors that affect weight measurement (e.g. latitude, altitude, level, side load, etc.) and have knowledge of methods to correct or avoid variations in weight due to those factors. II. CG Measurement <ol style="list-style-type: none"> a. Know the three static methods and two dynamic methods of CG measurement discussed in SAWE 2444. b. Be familiar with the instruments used in each of those methods. c. Understand the advantages and disadvantages of each method of CG measurement (i.e. accuracy, cost, time, multipurpose, etc.). d. Be able to calculate the CG of a test object using force and moment equations. III. MOI Measurement	I. Develop a test plan to measure the mass properties of a test object; this includes choosing the appropriate method and instrument to measure the desired mass properties as well as mitigating environmental factors that can affect the experiment. II. Define the orientation and coordinate system used to report mass properties data to the customer and communicate this coordinate system effectively in a deliverable. III. Be able to perform a dimensional inspection of a test object to determine if the object can meet the accuracy requirements of the customer.	I. Determine when actual measurement is warranted versus calculated values. II. Create a procurement plan for equipment acquisition and maintenance. III. Understand critical fixture design criteria (e.g. orthogonality, datums, positioning, alignment, etc.) and how to define these quantities for tool designers. IV. Develop a knowledge of past measurement experiences to be able to adapt and apply them to new test articles and requirements



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Item	Title author ¹	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
		<ul style="list-style-type: none"> a. Know the instruments/techniques used to measure MOI and how to mount the fixture and test object on the instruments. <ul style="list-style-type: none"> i. Inverted Torsion Pendulum ii. Hanging Wire Torsion Pendulum iii. Compound Pendulum b. Be able to calculate the MOI of the test object for each method from given equations c. Understand the advantages and disadvantages of the three MOI measurement techniques. d. Understand the effect of air mass on the MOI of the test object e. Understand the effect of damping on the MOI calculation; be able to calculate the damping from known equations and know when damping error can be considered insignificant. <p>IV. POI Measurement</p> <ul style="list-style-type: none"> a. Know the advantages and disadvantages of the two POI measurement methods discussed in SAWE 2444 <ul style="list-style-type: none"> i. Spin Balance Method <ul style="list-style-type: none"> 1. Know how to apply the Balancing Machine Theory 2. Be able to calculate CG offset and POI from given equations 3. Understand the types of unbalance that can occur when using a spin balance machine 4. Limitations of the Spin Balance Method ii. Moment of Inertia Method 		



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Item	Title author ¹	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
		V. Know the environmental factors that can adversely affect mass properties measurement instruments. VI. Know the difference between the body frame reference and the inertial frame reference		
4.5	Design Of Fixtures SAWE Paper 2190	<ul style="list-style-type: none"> • Establish a frame of reference • Effect of fixture error on MP Measurement • Desirable attributes of MP fixtures • Basic types of payload fixture interface • Generic types of fixtures • Custom Fixtures – Golf clubs, bombs, cars, space craft, 21' motor boat, etc • Peripheral hardware and software • Getting best performance from fixtures <p>Proper reporting of Fixture design choice, use.(ARS)</p>		
4.6	Customer and Contract Requirements By David Tellet	<p>Understand the basic relationships between customer and provider:</p> <ul style="list-style-type: none"> • Specification process • Not to exceed (NTE) values • Incentives and penalties • Information flow • Regulations • Technical Authority 	<p>Provide input to the contractual process:</p> <ul style="list-style-type: none"> • Review specifications • Develop NTE values • Assess MP performance • Enforce data flow process 	<ul style="list-style-type: none"> • Represent MPE in contract negotiations • Establish incentive policies • Develop information flow process • Develop and sign off on specifications and regulations
5.00	Engineering Knowledge			



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Item	Title author ¹	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
5.10	MP Engineering	<p>Fundamentals (i.e. estimate, calculate, weighing, report/control cycle)</p> <p>How to interpret, implement (with guidance) SAWE RPs & Standards.</p>	<ul style="list-style-type: none"> • Understand the interactions between disciplines, timing of decisions on mass properties, margin derivation etc. • Knowledgeable of all applicable <ul style="list-style-type: none"> • Cross Industry RPs • Wt Eng Handbook • SAWE MPE textbooks • For each industry, be familiar with <ul style="list-style-type: none"> • MPC RPs (M-1, A-7, A-3, G-1, etc) • Systems level knowledge • How to size the systems, estimate terminology • limit calculations • Safety & Operational limits • calculate MOI, POI, CoG, Wts 	<ul style="list-style-type: none"> • Develop new concepts that address new or reoccurring issues. • At least one paper required that should expand the knowledge base of MPE (expansion to be defined by VP-Tech). • Expert on the industry specific RPs, (M-1, A-7, A-3, G-1, etc) and textbook
5.20	System Engineering <i>(Perhaps INCOSE can help us with materials, training and materials?)</i>	Fundamentals	<p>Systems Engineering working knowledge</p> <ul style="list-style-type: none"> • Understand the double V • Understand product and methods equal to an Associate Certified System Engineer 	<p>Meet the qualifications of a Professional Systems Engineer Professional by INCOSE</p> <ul style="list-style-type: none"> • Experience • Actual certification is optional,
5.30	Sub Systems Structures, Fluids, Electrical, Mechanical, Cargo/Weapons, etc.	<p>Introductory Level (college text or a high level)</p> <p>Fill in the blank calculations</p>	<ul style="list-style-type: none"> • Understand similar systems in all industries, interactions and MP relationships • Derive high level weight related parametric for systems for analogies and checking of proposed concepts or changes. 	<p>In-depth knowledge about an industry or vehicle system.</p> <ul style="list-style-type: none"> • Sizing • Weight drivers • Various configurations • history of technology
5.40	Fundamentals	<p>Other engineering topics</p> <p>Math - Tensor calculus, Probability, statistics, scientific experimentation,</p> <p>Physics and Chemistry – 3 terms covering</p> <p>Engineering Classes – Strength of Materials, Statics & Dynamics, Fluid, electricity I & 2, metallurgy</p> <p>Other – Economics</p>		
6.00	Process	<p>Understand the design and acquisition processes (spiral, set based, US government, commercial airline, private citizen)</p>	<ul style="list-style-type: none"> • Implement processes • Define budgets • Define schedules 	<p>Develop a new department, with policies, procedures mentoring etc.</p>



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Item	Title author ¹	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
			<ul style="list-style-type: none"> • How to create a MPE Plan, Weighing Plan, In-service WCP • How to integrate MPE plan with SEMP, IMP etc • How to budget man-hours, and schedule activities • How to lean a process or organization to make MPC more effective (know of some things that work) 	
7.00	Software By Giorgio Prviati & Andy Schuster	<p>Understand how to use Excel Spreadsheets</p> <p>Difference between database types</p> <p>Understanding of programming fundamentals:</p> <ul style="list-style-type: none"> - loops - if cycles - data types - functions - input/output variables <p>Creation of a simple spreadsheet for mass properties combination (sum of mass, CoG, inertia)</p> <p>Creation of datasheets and/or program codes for standard measurement activities (mass and CoG measurements)</p> <p>Understanding of data exchange and data formats (standards, protocols and conventions).</p> <p>Understanding of the statistical tools of Excel, able to compute basic statistical variables form data series.</p> <p>Creation of clear and readable plots and graphs. Able to create a presentation in Power Point.</p>	<p>Manage the 3CAD tool by understanding</p> <ul style="list-style-type: none"> how to check catalog how to track changes update schedules part number vs MPE WBS Data exchange protocols RP M11 for CAD systems <p>Software management</p> <ul style="list-style-type: none"> - debugging - validation - version tracking - comments/manuals <p>Creation of datasheets and/or a program code for</p> <ul style="list-style-type: none"> - uncertainty computation (Motecarlo simulation and error propagation) - mass prediction (with targets, updates and tracking during a project evolution) - modeling a complex test activity with uncertainty management - assessing statistical trends and forecasting <p>Management of data exchange inside the workgroup and with clients and suppliers</p>	Set up a MPE database and analysis suite of software (requirements, testing, etc)
8.00	Analysis	Be familiar with statistical and probability tools	Enforce industry specific analysis guidelines:	Develop and approve data analysis tools:



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Item	Title author ¹	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
	By David Tellet	and methods: <ul style="list-style-type: none"> • Basic statistical variables: skew, mean, median, standard deviations, probability distributions. • Error analysis, precision, accuracy, sensitivity, bias. • Forecasting, extrapolation, curve fitting, confidence bounds, probability calculations. • Data analysis: exploratory data analysis, Monte Carlo method, ANOVA, risk analysis. 	<ul style="list-style-type: none"> • Data requirements (e.g., data dictionaries). • Evaluate and use data analysis tools: weight margin trends, forecasting, etc. • Develop and/or assess trend analysis, risk analysis, forecast reports. 	<ul style="list-style-type: none"> • Establish analysis guidelines (e.g., what is an outlier, minimum data set, etc.). • Approve data analysis reports. • Develop data collection and analysis process and requirements.
9.00	Mass Modeling by Bell Lee	<ul style="list-style-type: none"> • Basic concept knowledge of part/drawing indenture and work breakdown structure • Familiar with basic mass properties calculations • General understanding of mass properties tools • General understanding of CAD • General understanding of mass growth allowance (MGA) or equivalent uncertainty factors • Basic Equations Examples: Sum of mass, CoG, inertia equations, what do they mean 	<ul style="list-style-type: none"> • General understanding of product design (in your field) • Solid understanding of parametric estimation in relation to modeling • Solid understanding of how to apply MGA or equivalent uncertainty factors • Formulate modeling approach in relation to customer (internal and external) interface • Develop mass properties analysis tools (miscellaneous analyses) • Mentor junior engineers on modeling approach 	<ul style="list-style-type: none"> • Solid understanding of product design and concept development (in your field) • Experience with mass properties tool development and procurement process • First order estimation technique in relation to modeling for proposal and early program works • Subject matter expert in model reviews
10.00	Reporting	<ul style="list-style-type: none"> • How to use a client's WBS, how to build a WBS • Basic elements of a MP Report, and the audience • One Page executive summary • Content of a report (hierarchical by OBS, WBS, FBS), trends, changes etc • Describe How To: <ul style="list-style-type: none"> ○ present to management <ul style="list-style-type: none"> • report an MP impact or a change order • Uncertainty of mass, cog, inertia, buoyancy etc. • Extrapolate part weights when the exact size is not available. 	<ul style="list-style-type: none"> • How to check a MPE • How to Identify trends • Manage baselines and changes • determine loads • manage cycle times • How to track WIP 	<ul style="list-style-type: none"> • Develop budgets and schedule for Rpts • Determine design maturity curves • Develop Risk curves • Develop management dialog about weight control issues shown in report



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Item	Title author ¹	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
		Basic understanding of configuration management, weight goal allocation Weight Control Process - Working knowledge <ul style="list-style-type: none"> • Cradle to grave • Able to explain to others 		
99	Miscellaneous <i>Things that don't fit the outline above, but should be included. This is a temporary holding location</i>	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> • 	



5 Industry Specific - Requirements

Title Author ²	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
Commercial Aircraft			
Ground Vehicles		Knowledge of Hydrostatic Calculations 1. Ability to calculate hydrostatic properties 2. Understanding of the relationships between the hydrostatic properties 3. Ability to analyze Displacement and Other Curves Drawing 4. Knowledge of proper treatment of tanks, appendages, and freeflows etc. in hydrostatic calculations 5. Knowledge of ocean environments.	PMPE plus: <ul style="list-style-type: none"> • Making policy decisions and recommendations for ship class specific terms and definitions.
Marine 1 by David Tellet		Knowledge of Naval Architecture Terms and Definitions: 1. Ship coordinates, frame and deck numbering, major ship components 2. Ship types, uses 3. Hydrostatic terms and coefficients 4. Conditions A, A-I, N, N sub etc.	PMPE plus: <ul style="list-style-type: none"> • Reviewing and approving hydrostatic property calculations. • Establishing policy or standard methods for hydrostatic calculations.
Marine 2 by David Tellet		Knowledge of Hydrostatic Calculations 1. Ability to calculate hydrostatic properties 2. Understanding of the relationships between the hydrostatic properties 3. Ability to analyze Displacement and Other Curves Drawing 4. Knowledge of proper treatment of tanks, appendages, and free floods etc. in hydrostatic calculations 5. Knowledge of ocean environments.	PMPE plus: <ul style="list-style-type: none"> • Establishing policy or standard methods for weight control. • Review and approve weight control plans. • Development of recommended practices. • Establishment of required margins. • Approval of weight reports. • Development of mass properties sections of contracts.
Marine 3 By David Tellet		Knowledge of Weight Control Processes 1. Knowledge of weight estimating methods 2. Ability to develop and analyze weight control plans 3. Knowledge of recommended practices	PMPE plus: <ul style="list-style-type: none"> • Establishment of stability criteria. • Approval of stability calculations.

² Unattributed authorship written by Andy Schuster



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		4. Knowledge of weight reporting process 5. Knowledge of margin calculations 6. Knowledge of Weight Report Content and Format 7. Ability to evaluate weight report including ability to analyze weight and margin trends. 8. Knowledge of Contractual Requirements for margins, incentives, liquidated damages, and deliverables.	<ul style="list-style-type: none"> • Establishing policy or standard methods for stability calculations. • Establishing policy or standard methods for inclining experiments and trim dives.
Marine 4 By David Tellet		Knowledge of Stability Requirements and Processes 1. Knowledge of GM/BG and righting arm criteria 2. Ability to perform a stability analysis including: <ul style="list-style-type: none"> a) Ability to calculate and analyze righting arm curves b) Knowledge of free surface calculations (large and small) c) Ability to apply Surface Ship and Submarine stability criteria 3. Ability to collect and evaluate stability data <ul style="list-style-type: none"> a) Knowledge of spreadsheet and database tools b) Knowledge of basic statistical functions c) Ability to develop and analyze class-wide stability trends 4. Ability to perform an inclining experiment or trim dive.	PMPE plus: <ul style="list-style-type: none"> • Establishment of reporting processes and requirements. • Approval of mass properties reports. • Reporting of mass properties to senior management. • Negotiating with other parties with regard to mass properties requirements, limits, margins, etc.
Marine 5 By David Tellet		A. Knowledge of In-Service Reporting Requirements and Processes 1. Knowledge of Customer or Government reporting requirements. <ul style="list-style-type: none"> a) Reporting sequence and schedule b) Responsibilities of all parties c) Content and format of reports 2. Ability to work with shipyards, government entities, customers, certification bodies. <ul style="list-style-type: none"> a) Resolving errors b) Providing guidance a) Presentation of evaluations and recommendations 	PMPE plus: <ul style="list-style-type: none"> • Development of design guidance documents. • Approval of ship specifications.



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Title Author ²	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
Marine 6 By David Tellet		Knowledge of Design Guidance Documents including design notebooks, ship specifications, etc.	
Marine 7 By Andy Schuster	<ol style="list-style-type: none"> 1. Hydrostatic based draft calculations 2. HVAC, weapon systems, hotel, cargo 3. Materials 4. Weight Reduction calculations, <ul style="list-style-type: none"> • 	<ol style="list-style-type: none"> 1. Describe a Vendor weight control plan 2. Be able to identify and use 10 of the 14 weight estimating methods defined in the RPs (14 and C-09)- 3. Add Requirement 6 Validation (weighing) 4. Describe weighing of a small vs large object (40 oz vs 40,000 tons) 	Derive a Bill of Materials from a concept level weight estimate.
Military Aircraft³ By Jeff Vaughn		<ol style="list-style-type: none"> a. Familiar with the Joint Service Technical Manual – Aircraft Weight and Balance: 01-1B-50 and 55-1500-342-23 b. Familiar with the SAWE Recommended Practice RP-7 c. Familiar with the SAWE Recommended Practice RP-8 d. Witness/Conduct Aircraft Weighing e. Develop Specification/SOW Requirements for Mass Properties f. Develop/Review Aircraft Weighing Procedures g. Develop/Review Chart A using RP-7 and Joint Weight and Balance Manual guidance. h. Develop/Review Weight and Balance Checklist using Service Regulations and Joint Weight and Balance TM guidance. i. Develop/Review Modification weight and balance analysis Reports. j. Develop/Review Weight and Balance section of Modification Work Order (MWO, or Time Compliance Technical Order (TCTO). 	<ol style="list-style-type: none"> a. Advisor to System Safety on Mass Properties issues. b. Develop/Review the Mass Properties Control Management Plan (MPCMP) for each aircraft system. c. Manage a team of Mass Properties Engineers. d. Develop/Review Mass Properties Criteria for Military Airworthiness e. Develop/Review Internal Standard Operating Procedures (SOP) for various mass properties products

³ Missing: (a) Estimate of Aircraft Design and MP refinement to aircraft Build and production; (b) Government Independent Estimate of Design.



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		k. Familiarity and use of Electronic Forms (such as AWBS) for maintaining the DD Form 365 series records. l. Review of flight clearance forms containing weight and balance instructions. m. Develop/Review Aircraft System Level Weight Reports developed IAW RP-7 & RP 8 instructions. n. Develop/Review Aircraft Weight and Balance Loading and Weighing Instructions (aka Chart E) IAW RP-7 and the Joint Weight and Balance TM.	
Missiles & Space By Pat Borden & Robert Zimmerman General Skills - Discretion / Latitude	<ul style="list-style-type: none"> • Applies discretion and judgment to complete assignments of moderate scope and complexity. • Works under very general supervision, usually by a Lead Mass Properties Engineer, and must be able to follow specific, detailed instructions. • Work is reviewed for soundness of technical judgment and overall adequacy. 	<ul style="list-style-type: none"> • Independently determines and develops approach to solutions, performing work without appreciable direction. • Exercises considerable latitude in determining technical objectives and approaches to assignment. • Work is reviewed upon completion for adequacy in meeting objectives and from a relatively long-term perspective for desired results. 	<ul style="list-style-type: none"> • Works under consultative direction towards predetermined long-range goals and objectives, acting independently to uncover and resolve issues associated with the development and implementation of operational programs. • Assignments are often self-initiated, determining and pursuing courses of action necessary to obtain desired results. Plans research & development programs and recommends technological application programs to accomplish long-range objectives. • Work is checked only to the effectiveness of results obtained, typically requiring a long-term perspective. • Virtually self-supervisory.
Missiles & Space By Pat Borden & Robert Zimmerman General Skills - Impact	<ul style="list-style-type: none"> • Contributes to the completion of milestones associated with specific projects. • Failure to achieve results or erroneous decisions or recommendations may cause delays in program schedules and may result in the allocation of additional resources. 	<ul style="list-style-type: none"> • Guides the successful completion of major programs/projects and may function in a project leadership role. • Erroneous decisions or recommendations would typically result in serious program delays and considerable expenditure of resources along with failure to achieve major organizational objectives. 	<ul style="list-style-type: none"> • Designs research and develops highly advanced new applications resulting in new products/business opportunities. • Erroneous decisions or recommendations would typically result in failure to achieve critical organizational objectives and affect the image of the organization's technological capability, along with having a long-term negative effect on organization's reputation and business, and financial posture.
Missiles & Space Pat Borden	<ul style="list-style-type: none"> • Frequently uses and applies technical standards, principles, theories, concepts, and techniques to 	<ul style="list-style-type: none"> • Complete understanding and wide application of technical principles, theories and concepts, in the field. 	<ul style="list-style-type: none"> • Exhibits an exceptional degree of ingenuity, creativity, and resourcefulness.



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Title Author ²	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
Knowledge	complete assignments of moderate scope and complexity.	<ul style="list-style-type: none"> Applies extensive technical expertise, and has full knowledge of other related disciplines. 	<ul style="list-style-type: none"> Applies and/or develops highly advanced technical technologies, scientific principles, techniques, theories and concepts. Viewed as an expert within the field.
Missiles & Space By Pat Borden & Robert Zimmerman General Skills - Liaison	<ul style="list-style-type: none"> Contacts are primarily internal company contacts with infrequent inter-organizational and outside customer contacts on routine matters. 	<ul style="list-style-type: none"> Contacts are frequently inter-organizational and with outside customers. Represents the organization as the prime technical contact on contracts and projects, providing solutions to difficult technical issues associated with specific projects. Interacts with senior external personnel on significant technical matters often requiring coordination between organizations. 	<ul style="list-style-type: none"> Serves as organization spokesperson on advanced projects and/or programs and advises management and customers on advanced technical research studies and applications. Consultant to top management in long-range planning concerning new or projected areas of technical research and advancements. Prime external spokesperson for the company on highly significant matters relating to research, engineering matters, programs, and technical capabilities. Often instrumental in attracting and obtaining major new business.
Missiles & Space By Pat Borden & Robert Zimmerman General Skills - Problem Solving	<ul style="list-style-type: none"> Provides and/or develops solutions to a variety of technical problems of moderate scope and complexity. 	<ul style="list-style-type: none"> Develops and/or provides technical solutions to complex problems which require the regular use of ingenuity and creativity. Solutions are imaginative, thorough, and practicable, and consistent with organization objectives. 	<ul style="list-style-type: none"> Provides solutions which are highly innovative and ingenious on unusually complex technical problems. Develops information which extends knowledge in a given field. Information may form the basis of newly developed concepts, theories, and products.
Missiles & Space By Pat Borden & Robert Zimmerman General Skills	<ul style="list-style-type: none"> Bachelors degree from an accredited college in an engineering/technical discipline, with 2 years of professional experience; or no experience required with a related Masters degree. Considered experienced and emerging career level, but still a learner. 	<ul style="list-style-type: none"> Bachelors degree from an accredited college in an engineering/technical discipline, with 9 years of professional experience; or 7 years of professional experience with a related Masters degree. Considered an emerging authority. 	<ul style="list-style-type: none"> Bachelors degree in an engineering/technical discipline from an accredited college in a related discipline, with 20 years or more of professional experience; or 18 years with a related Masters, or 15 years with a related PhD degree. Considered an expert, authority in discipline, and viewed as the most senior authority in discipline.



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- Typical Minimums			
Missiles & Space By Pat Borden & Robert Zimmerman Technical Skills – General Skills	<ul style="list-style-type: none"> • Interprets detailed designs from manufacturing drawings or standard modeling software tools. • Knowledge and some proficiency with Microsoft Word, Excel and Power Point, solid modeling applications, and other software tools. • Familiar with and perform basic mechanical analysis including statics, kinematics, error analysis, tolerance stack up, etc. 	<ul style="list-style-type: none"> • Expert with standard tools and techniques including improvements and development. • Competent with Microsoft Word, Excel and Power Point, solid modeling applications, with an understanding of other software analysis tools. • Performs complex mechanical analysis including statics, kinematics, error analysis, tolerance stack up, etc. 	<ul style="list-style-type: none"> • Oversight activities of engineers working with standard tools and techniques. • Competent with all communication applications as well as complete understanding of all analysis tools. • Competent in complex mechanical analysis including statics, kinematics, error analysis, tolerance stack up, etc.
Missiles & Space By Pat Borden & Robert Zimmernam Technical Skills – Mass Properties Engineering Skills	<ul style="list-style-type: none"> • Calculates mass properties (mass, 3 axis centers of gravity, and moments of inertia) of components and performs summation calculations into assemblies. • Understanding of mass properties concepts, able to perform calculations by hand, and develop simple software calculation tools. • Understanding of standard mass properties analysis concepts like transformations, rotations, mass distributions, and uncertainties; applies skills to preliminary design estimation. • Familiar with mass properties calculation tools. • Understand requirements flow-down and subsystem mass properties allocations. • Understand development of program SOW and cost quotes. • Familiar with AIAA and SAWE mass properties engineering standards. 	<ul style="list-style-type: none"> • Competent in calculating the mass properties, including assembly summations. • Expertise in mass properties analysis and verification. • Able to develop complex software calculation tools. Able to provide technical direction and train junior engineers in mass properties analysis skills and tools. • Able to perform complex mass properties estimation of preliminary design concepts, modeling and analysis, reporting, and verification and model validation. • Understands mass properties interactions of other mechanical analysis groups including stress, structural loads and dynamics, thermodynamics, aerodynamics, propulsion and power systems, as well as subsystem designers to promote mass properties efficient design alternatives. • Able to develop and document requirements flow-down based on program performance requirements. • Able to develop mass properties support requirements and schedules for the program. 	<ul style="list-style-type: none"> • Demonstrate complete expertise in the mass properties field.
Missiles & Space	<ul style="list-style-type: none"> • Competent verbal and written communication skills. 	<ul style="list-style-type: none"> • Proper verbal and written communication skills to the level of program management. 	<ul style="list-style-type: none"> • Outstanding verbal and written communication skills to all levels of program and management.



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Title Author ²	AMPE Associate Mass Properties Engineer	PMPE Professional Mass Properties Engineer	EMPE Expert Mass Properties Engineer
By Pat Borden & Robert Zimmerman Technical Skills – Communications			
Missiles & Space By Pat Borden & Robert Zimmerman Technical Skills – Leadership	<ul style="list-style-type: none"> • Participate and interact with other engineers to investigate and promote more mass properties efficient designs. • Participate as fully-competent and teachable mass properties team member of a program, taking ownership of small areas of technical activity. 	<ul style="list-style-type: none"> • Train junior engineers in mass properties analysis skills and tools and provide technical direction. • Supervise junior engineers in ever-increasing complex mass properties analysis and verification skills. • Train junior mass properties engineers to promote mass properties efficient designs. • Supervise and support mass properties engineers to promote mass properties efficient designs. • Lead and oversee the mass properties effort of a large program or several small programs. • Support a multi-disciplinary team and solve program mass properties issues. 	<ul style="list-style-type: none"> • Coach, mentor, and train mass properties engineers in complex analysis and verification. • Act as a technical consultant to programs and customers within the company, while supporting efforts to promote mass efficient designs. Support peer reviews when necessary. • Lead and oversee the mass properties effort multiple large programs. • Competently lead a multi-disciplinary team and solve complex program MP issues.
Missiles & Space By Pat Borden & Robert Zimmerman Standards & Processes	<ul style="list-style-type: none"> • Familiar with mass properties verification methods and the maintenance, calibration, and the operations of measurement instruments like platform scales, load cells and moment tables. • Familiar with Mass Properties Engineering standards and Mass Properties Control processes and documentation. 	<ul style="list-style-type: none"> • Understand all mass properties verification methods and techniques. • Develop complex mass properties verification methods, including static and dynamic balance measurement instruments. • Develop new and innovative mass properties tools and techniques. • Completely understands Mass Properties Engineering standards and Mass Properties Control process, with ability to modify and streamline standards and process where applicable. 	<ul style="list-style-type: none"> • Develop new and innovative mass properties tools and techniques in analysis, verification, and control. • Develop new industry-wide mass properties engineering standards and control processes.
Missiles & Space Pat Borden	<ul style="list-style-type: none"> • Estimate and/or calculate mass properties, including mass, 3-axis center of mass, moments of inertia, and products of inertia. 	<ul style="list-style-type: none"> • All AMPE duties, plus the following: • Create and make presentations at program design reviews. 	<ul style="list-style-type: none"> • All CMPE duties, plus the following: • Subject Matter Expert on everything relating to Mass Properties Engineering; researching as necessary to



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MPE Specific Job Duties	<ul style="list-style-type: none"> • Create and update mass properties model using relevant design data along with the estimated or calculated mass properties. • Perform simple and/or basic trade studies. • Prepare and publish reports, graphs and visual presentation aids. • Perform simple and/or basic mass properties measurements, including minor piece parts and subassemblies where results are not critical. • Interpret measurement data into final user values using data reduction analysis. • Support mass properties requirement derivation. • Support Mass Properties Control Boards. • Document and publish analysis reports, memos, and other reference material. • Successful completion of the SAWE Associate Mass Properties Engineer (AMPE) test. 	<ul style="list-style-type: none"> • Lead mass properties audits, with program and customer visibility. • Develop test procedures, coordinating with other engineering groups to acquire proper data while managing complex interfaces. • Perform complex mass properties measurements, including major assemblies where results are critical. • Facilitate Mass Properties Control Boards and weight reduction teams. • Lead mass properties efforts on small to large programs. • Supervising mass properties functions. • Determine tasks, priorities, and schedule work on programs. • Work with integrated product teams and interact with many other engineers, technicians, subcontractors, and customer on programs. • Interface with senior program and customer management, including advising on critical technical issues and their relationship to technical and programmatic performance. • Successful completion of the SAWE Certified Mass Properties Engineer (CMPE) test. 	<ul style="list-style-type: none"> ensure appropriate knowledge to implement proper processes. • Mentor other mass properties engineers to improve mass properties knowledge and ensure their success. • Lead mass properties audits, with senior management and customer visibility. • Lead mass properties efforts on large programs critical to business success, typically on a high-visibility and customer-focused programs. • Ensure mass properties functions are carried out through other senior mass properties engineers. • Maintain discipline and handle personnel issues of mass properties support team. • Provide technical direction to program management and customer to ensure programmatic performance. • Successful completion of the SAWE Expert Mass Properties Engineer (EMPE) test.
Offshore 1		Need endorsement or recognition of the oil companies and contractors might like it, because it would eliminate risk of the critical engineering function. That is they could hire knowledgeable people.	
Offshore 2		Need to make it easy for a part time MPE lead to qualify. (Project Engineer, Discipline manager) Ranging from Project Engineers through engineer	
Offshore 3		Understanding of ISO 19905 and the difference of requirement for each risk class.	
Offshore 3		TLP CoG diagram, use development etc	
Offshore 4		Risk assessment and management	



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Offshore 5	1. Hydrostatic based draft calculations 2. HVAC, weapon systems, hotel, cargo 3. Materials 4. Weight Reduction calculations, 5. know the Offshore training class and RPs	1. Describe a Vendor weight control plan 2. Be able to identify and use 10 of the 14 weight estimating methods defined in the RPs (14 and C-09)- 3. Add Requirement 6 Validation (weighing) 4. Describe weighing of a small vs large object (40 oz vs 40,000 tons)	Derive a Bill of Materials from a concept level weight estimate.



6 References & Revision history

6.1 References

SAWE Paper 1655 Training MPEs

SAWE Paper 3129 Ford Weight Engineering Academy

6.2 Revision History

Revision 17

- Included sections 4.4.2 and 5. Military Aircraft provided by Jeff Vaugh, 6/1120
- Also did a check that all prior changes were included.

Details of past revisions can be found in “SnP-9, SAWE CA-1 Standards Development Record” in Group Office.