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A Prototype for NASA Educator Resource Collaboration: A Narrative Case Study Examining Development of EPDC's *Balancing Act-Spacecraft Mass Properties* Digital Badge

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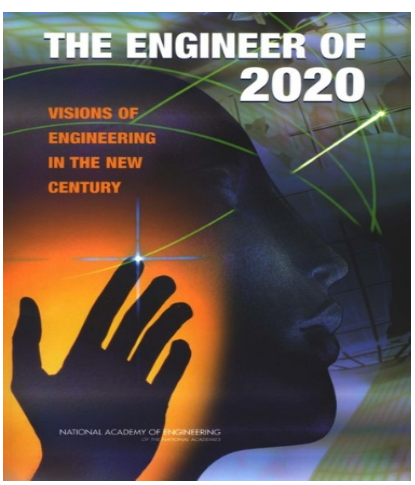
"How can engineers best be educated to be leaders, able to balance the gains afforded by new technologies with the vulnerabilities created by their byproducts without compromising the well-being of society and humanity?" (NAE, 2004)

INTRODUCTION

Technology pervades much of today's modern society and it has become nearly ubiquitous across the U.S. education system (Bowen, 2013; Collins, & Halverson, 2009). Whether it is "traditional" online courses, digital badges (i.e., micro-credentials), or Z-degrees utilizing open educational resources (OERs), rapidly evolving technologies are continuously changing the K-12, higher education and teacher professional development (PD) sectors (Gamrat, Zimmerman, Dudek, & Peck, 2014; U.S. Department of Education Office of Educational Technology, 2017; Wiley, Williams, DeMarte, & Hilton, 2016). Accordingly, online PD resources, as exemplified by NASA STEM EPDC's digital badges, continue to increase in popularity (Dawley, Rice, & Hinck, 2010; Martinez Ortiz, Weis, & Merritt, 2018). Primary reasons given for this trend include: 1) it allows teachers to engage in unique learning opportunities not available in their geographic area, 2) teachers can access online resources at times that are convenient for them, and 3) educators can customize their PD to fit distinctive learning styles and current classroom needs (BCG, 2015; Gamrat *et al.*, 2014).



LITERATURE – ENGINEERING EDUCATION

These instructional technology developments occur at a critical time for the future U.S. workforce. Members of the Baby Boom generation have reached retirement age, creating difficulties in finding enough qualified workers from this country to fill available and emerging technical positions (Boze, 2018; Rosenberg, 2018; Space Frontier Foundation, 2012). In anticipation of a potential crisis for engineering fields, the National Academy of Engineering (NAE) (2004) commissioned *The Engineer of 2020*, a comprehensive report of how future engineers should be prepared for differing

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leadership roles in not just traditional technical careers, but also the industry, government, nonprofit and academia sectors. Panel members argued that the next generation of engineers had to learn not only technical content knowledge, but also 21st-century skills such as collaboration, writing, speaking, information literacy, and an appreciation for varied cultural and global contexts (NAE, 2004). In response, the Accreditation Board for Engineering and Technology (ABET), a global entity that accredits postsecondary engineering education programs, quickly aligned to the NAE's recommendations, which triggered various responses in higher education as programs sought reaccreditation. ABET commissioned several National Science Foundation (NSF)-funded studies in order to examine some of the most effective strategies colleges and universities were using to meet ABET's new accreditation guidelines (Lattuca, Terenzini, Knight, & Ro, 2014; Terenzini, Lattuca, Kremer, Plumb, & Trautvetter, 2008). More recently, leaders of professional organizations, such as the Society of Allied Weight Engineers (SAWE), are taking more proactive roles in identifying steps their members can take to support formal and informal education efforts that inspire students as early as middle school grades to consider future careers in their particular engineering discipline (Boze, 2018).

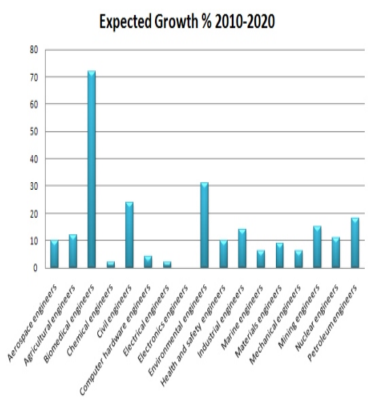


*Figure 1: Employment Growth Projections for Engineering Occupations (*Credit: U.S. Bureau of Labor Statistics [BLS]*)*

"…projected growth across all engineering occupations as being 7-13%...during 2012-2022 decade" (U.S. BLS, 2019)

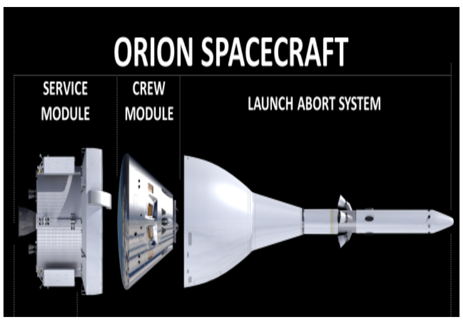
OVERVIEW – *Balancing Act-Spacecraft Mass Properties*

For over a century, employees of NASA's Langley Research Center (LaRC) have made contributions in the fields of aeronautics, science, and technology that provide game-changing innovations across all of NASA's missions and enhance U.S. STEM education with one-of-a-kind assets. LaRC's Office of Education, now Office of STEM Engagement (OSTEM), team collaboratively works with subject matter experts (SMEs) across all mission directorates to identify openings for placement of interns (workforce development) and mission resources for inclusion in various face-to-face and virtual events (educator professional development and student engagement). An ongoing partnership with the Flight Test Management Office (FTMO), tasked with mass properties [allied weight] engineering testing of flight test hardware for NASA's *Orion* spacecraft and its Launch Abort System (LAS), and Public Affairs Office (PAO) yielded an opportunity in 2018 for OSTEM to develop a series of educational products in support of the Ascent Abort-2 (AA-2) flight test, scheduled for summer 2019. The purpose of this paper is to document the novel customer-service business model approach that yielded NASA STEM EPDC's *Balancing Act-Spacecraft Mass Properties* digital badge, which blends EPDC's expertise in digital badging and culturally relevant teaching (CRT), FTMO's mass properties technical knowledge, and PAO's outreach needs in advance of the AA-2 flight test.

METHODS – Digital Badge Development

This paper utilized a narrative research case study design in order to document the 'life' history of the *Balancing Act-Spacecraft Mass Properties* digital badge from concept to development to publication (Creswell, 2013; Stake, 2000). Highly contextualized, narrative research collects data from a variety of qualitative sources in order to construct collaborative, chronological stories about a specific individual, location or situation (Creswell, 2013). Furthermore, case study methodologies afford investigators the opportunity to conduct exploratory and descriptive research about single (or multiple) object(s) within a real-life scenario bounded by space and time (Creswell, 2013; Stake, 2000). The overarching objective, therefore, of any case study research is to advance understanding of the general phenomenon under examination and extend the boundaries of that particular research field (Yin, 2014).

The researcher utilized two data collection methods during badge development: visual observation and document analysis. An unobtrusive observation occurred informally during a late January 2018 meeting for selected OSTEM, FTMO and PAO members, who briefed each other on *Orion* Ascent Abort-2 flight test mission objectives, mass properties technical knowledge, and possible solutions for effectively disseminating the project's content and message to students, teachers and the public. For document analysis, the researcher reviewed email messages, previously produced photographs and videos, FTMO technical documents, and EPDC badge development materials from mid-spring to summer 2018 (Altheide, & Schneider, 2017; Bowen, 2009). In doing so, the author constructed a timeline of salient events, or "turning points" (Creswell, 2013, p. 72) in the evolution of a high-quality STEM education resource, NASA STEM EPDC's *Balancing Act-Spacecraft Mass Properties* digital badge, using a highly collaborative creative process. Finally, to verify the badge's accuracy, the writer conducted member checks with representatives of the OSTEM, FTMO and PAO teams (Creswell, 2013).



Credit: NASA

CONTEXT – Pre-Badge History

> "For the first time in a generation, NASA is building a human spacecraft for deep-space missions, …including to the vicinity of the Moon and Mars. Named after one of the largest constellations in the night sky and drawing from more than 50 years of spaceflight research and development, …*Orion* will serve as the exploration vehicle that will carry the crew to space, provide *<u>emergency abort capability</u>* (emphasis added), sustain astronauts during their missions and provide safe re-entry from deep space return velocities" (NASA, 2017).

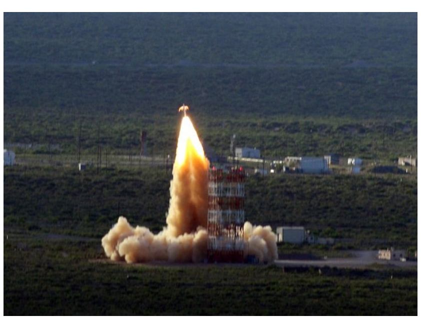
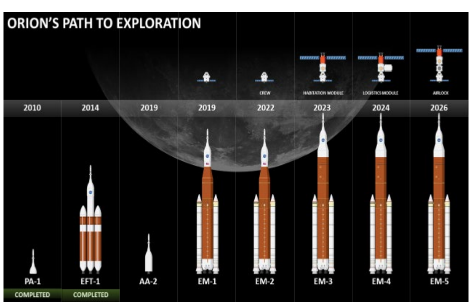


Photo credit: NASA

In 2010, NASA conducted the Pad Abort-1 (PA-1) flight test, which was an initial assessment of *Orion*'s fully integrated Launch Abort System (LAS), with a crew capsule, for the Agency's *Space Launch System (SLS)*. NASA EDGE, a Langley Research Center (LaRC)-based video podcast (vodcast) team, took viewers on a behind-the-scenes look at

Photo credit: NASA



Credit: NASA

Orion's LAS project before documenting the entire PA-1 event in New Mexico (NASA EDGE, 2010a-c). With NASA EDGE serving as a public outreach and education initiative, its staff frequently contribute to other LaRC Office of STEM Engagement (OSTEM) events (e.g., educator professional development institutes) as their schedules permit. Most notably though, NASA EDGE also serves as a potential resource to connect the OSTEM team with subject matter experts (SMEs) in support of educator and student engagement activities.

As the NASA EDGE team documented PA-1 in 2010, they prominently featured mass properties engineers from LaRC's Flight Test Management Office (FTMO); these individuals had also appeared in several NASA Launchpad (eClips) featurettes (NASA EDGE, 2010a-c; NASA eClips/Launchpad, 2009a-b). Through these productions, LaRC's FTMO mass properties engineers became familiar with individuals in the then-Office of Education (OED), now OSTEM. Independent of these developments, senior leadership of the Society of Allied Weight Engineers (SAWE), the professional organization for mass properties engineering, commissioned a podcast series for release at their 2008 International Conference. Intended as a recruiting tool to inspire the next generation of mass properties engineers, the podcasts featured careers of selected SAWE members, including a NASA LaRC FTMO engineer working on *Orion*'s LAS (SAWE, 2008).

CATALYST – Langley Research Center's Centennial

NASA had originally planned a series of tests for the *Orion* LAS after PA-1, but before its final integration with the *SLS* for the Exploration Mission-1 (EM-1) flight. However, given budgetary constraints, the Agency opted to combine them into a single follow-up verification event: Ascent Abort-2 (AA-2) (Cutright, 2018). A key step in ensuring that *Orion* and its LAS was ready for its tentative summer 2019 AA-2 flight was mass properties measurements of a full-size *Orion*

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command module boilerplate. While this particular test article will not fly in space, it replicated the anticipated flight mass configuration for the one that will. By placing ballast blocks in known locations of instrumentation and crew, Langley FTMO engineers were able to take measurements for precisely calculating the capsule's center of gravity (CG) down to an area no larger than a 6-sided dice on the 11-foot x 16-foot, 22,899-pound structure. As it turned out, the FTMO mass properties engineers were making final preparations for these measurements as the Center held an Open House, the culminating event of Langley's Centennial Year celebration, "*A Storied Legacy, A Soaring Future*."

Photo credit: NASA Langley

Given a rare opportunity to visit the normally restricted-access research facility, over 20,000 people from across the country came to tour LaRC's historic facilities and learn about the work that "…continues to equip the nation with technology for the future…" (Vitug, 2017). Exhibits showcasing Langley's contributions to *Orion* and *SLS* were among the day's highlights, serving as tangible reminders of NASA's commitment to human exploration of space beyond low-Earth orbit (McDonald, 2017). Prior to the Open House, the FTMO team had deliberated over how best to engage a non-technical audience with the mass properties research they were about to conduct in support of the *Orion* LAS Ascent Abort-2 flight test. The engineers brainstormed ideas and they eventually selected two activities: a pipe cleaner/craft stick modeling activity for *Orion*'s LAS (using paper clips as "ballast blocks"), and a mechanical forearm lever exercise (using a PVC-pipe T-assembly with S-hooks for a two-pound weight). Both were well-received, impressing upon Open House visitors of all ages the importance of calculating *Orion*'s center of gravity so that the *SLS* does not experience torque (i.e., rotation) during launch.

Photo credit: NASA Langley

COLLABORATION – *Balancing OSTEM, FTMO & PAO*

Observing the success of these simple instructional activities at Langley's Centennial Open House led the FTMO

"For the first time in a generation, NASA is building a human spacecraft for deep-space missions …including to the vicinity of the Moon and Mars. Named after one of the largest constellations in the night sky, …Orion will serve as the exploration vehicle" (NASA, 2017)

Credit: NASA

and Public Affairs Office (PAO) teams to wonder if the resources could be "marketed" to teachers and students as *Orion*'s 2019 Ascent Abort-2 (AA-2) test approached. The lead engineer for *Orion*'s mass properties testing and Langley's *Orion* Public Affairs Specialist contacted the Education Specialist Lead, who scheduled a joint meeting involving representatives of the OED (now OSTEM), FTMO and PAO teams for late January 2018. Attendees first heard from FTMO mass properties engineers who presented technical background information on *Orion*'s LAS, the then-upcoming mass properties measurements (scheduled for February 2018), and flight objectives for AA-2. The mass properties lead engineer explained the impetus for selecting the two instructional activities (i.e., Centennial Open House) before leading everyone through the pipe cleaner/craft stick modeling exercise and demonstrating the mechanical forearm lever task. Langley's Public Affairs Specialist followed with an outline of the *Orion* Communications (COMMS) team's public outreach efforts for AA-2, which included an approximately 90-second-long computer animation of what the targeted summer 2019 flight would look like. With the briefings complete, everyone then participated in a brainstorming session to identify possible strategies for disseminating the content knowledge and instructional resources. The consensus from this meeting was that OSTEM would add a kit containing the pipe cleaner/craft stick modeling activity to its inventory for face-to-face events and then develop an online training module for educators and partners. With most of the OSTEM's online training intended for NASA scientists and engineers who perform occasional public outreach duties, the more likely destination for this product was the Agency's internal System for Administration, Training, and Educational Resources for NASA (SATERN) platform. However, given the success of a previous digital badging project (the Langley Centennial badges) and the expertise of Langley's EPDC Specialist in online EPD, the Education Specialist Lead also proposed the Texas State/EPDC digital badging system as an external location.

Moving forward with a decision regarding where to house the training module had to wait until after FTMO's mass properties measurement project, which took up most of

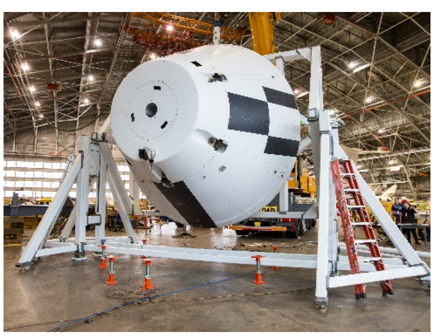
February 2018. In early March, the lead engineer forwarded the slide deck she had used for January's joint meeting without any modifications, although she had planned on:

> "…adding pictures from the actual [mass properties] testing and further connecting the dots between the importance of mass properties and 'Stability and control' which is a function of mass properties, geometry, and aerodynamics [which is also a function of mass and geometry]…" (Cutright, personal communication, March 8, 2018).


Credit: NASA Langley *Orion* FTMO

With the focus on technical content, the Education Specialist Lead still envisioned a "training" when the OSTEM team met for its regularly scheduled tag-up a week later. However, based on Specialists' schedules, the Lead formally assigned the project to Langley's EPDC Specialist who was, at the time, focusing more time on a variety of badge development projects (e.g., "soft skills" badges for NASA Internships & Fellowships [NIFS], Virginia undergraduate engineering programs, etc.). In the email detailing parameters of the commission, the Lead instructed that:

> "The idea is to create a training similar to the digital badges, that can be used on the [Texas State] website but also as a Satern training. … *Objective*: To create a training module on the AA-2 (Ascent Abort-2) that provides necessary background knowledge to give educators and partners the understanding needed to confidently present the activity and relate it to the real world challenges NASA's AA-2 mission is addressing" (Brush, personal communication, March 15, 2018).


Credit: NASA Langley *Orion* FTMO

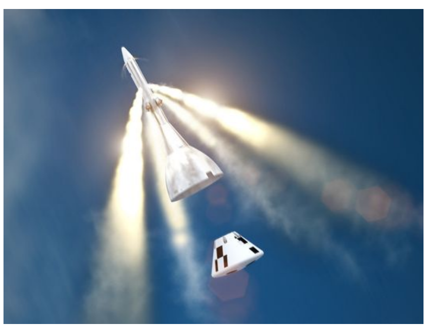
With a preferred deadline of April 30th, the Langley EPDC Specialist replied approximately two weeks later with a rough outline for a digital badge. Langley's EPDC Specialist was intentional in the decision to select this format for the new "training," as opposed to the previous frontrunner SATERN module, because EPDC's digital badge committee had concurrently received a charge to develop and release five [5] new badges per month (Culivan and Weis, personal communication, March 22, 2018). In addition, the EPDC

Specialist had much more experience in constructing online digital badges, first with NASA's *Teacher Learning Journeys (TLJ)* and then the NASA STEM EPDC badging site, than with SATERN training module environment. Thus, with approval of both Langley and EPDC teams, the EPDC Specialist submitted the following notes to the Education Specialist Lead for an AA-2 educator badge with five [5] modules:

> "*Description*: From the earliest days of manned spaceflight, NASA has incorporated various safety systems into its launch vehicles, including an escape system that could pull a crew capsule to safety during the earliest moments of a rocket launch. Although critical to the success of any mission, a launch abort system adds mass and alters the physical properties of a launch vehicle. Thus, NASA engineers carefully model and measure the mass properties of an abort system before its integration with the launch vehicle.
>
> *Objectives*: 1) Learn about the *Orion* crew capsule, its Launch Abort System (LAS), & mass properties associated with rocket design
> 2) Discover the history behind launch abort systems & their importance to crew safety
> 3) Design a replica (or rocket prototype), measure/observe mass properties, & make improvements as necessary; and
> 4) Demonstrate how these activities can be implemented in the classroom" (Weiss, personal communication, March 27, 2018).

With minimal revisions and approval to move forward, Langley's EPDC Specialist crafted the first draft of the *Orion* Ascent Abort-2 educator professional development digital badge, tentatively titled, '*Finding Balance: Rocket Mass Properties*.' As part of the development process, it was necessary to reach back out to the FTMO mass properties engineer and Langley's *Orion* Public Affairs Specialist for access to pictures that would illustrate various concepts in the badge. Although the EPDC Specialist had received the original slide deck provided by FTMO, she had to request the external website link where presentation pictures were located due to a unique uploading quirk of the EPDC digital badging platform. Given an uncertainty over what updates the FTMO mass properties engineer and Langley's *Orion* Public Affairs Specialist had received, the EPDC Specialist respectfully included a short progress report on development of the "training materials" with her request. To build consensus for the project's changed format, the EPDC Specialist also extended an invitation to participate in the review process:

> "…requested that I create training materials related to the AA-2 test. The first product will be a potential digital badge that K-12 STEM educators can complete for professional development (PD) credit. …introduces educators to mass properties, Orion's LAS and the AA-2 test, and educational activities… Once I have a draft ready, it will go through a review process, which includes feedback from you… If it meets your and EPDC's approval, the digital badge will also be eligible for a blog post and several PD webinars (broadcast from Langley) to advertise its availability to K-12 teachers nationwide" (Weiss, personal communication, April 24, 2018).


Credit: NASA

The response was overwhelmingly positive as both Langley's *Orion* Public Affairs Specialist, "can't wait to help promote this!," and the FTMO's mass properties engineer, "I look forward to seeing what you have created!" replied with enthusiastic support (Damadeo and Cutright, personal communication, April 24, 2018). Most importantly, FTMO granted access to their team's shared drive to both the Education Specialist Lead and EPDC Specialist. No longer was the prospective digital badge restricted to pictures from the slide deck; now there was a full-range of material to draw from for both ensuring accuracy of the badge's content as well as making it more visually appealing. With selected photos and instructional activity diagrams exported to an external website for successful incorporation into the badging platform, the first iteration of the *Orion* Ascent Abort-2 digital badge was released to both the EPDC badging committee and Langley collaborators for their feedback.

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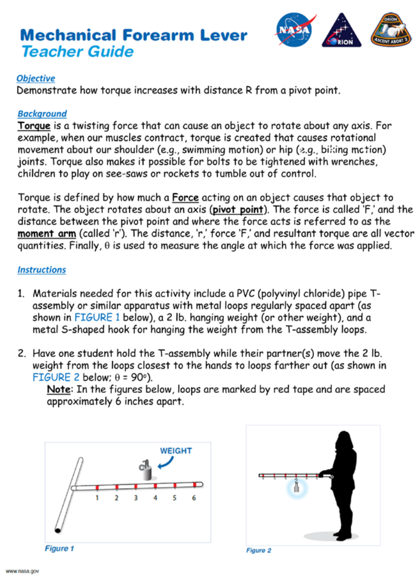


Mechanical Forearm Lever
Teacher Guide

Objective
Demonstrate how torque increases with distance R from a pivot point.

Background
Torque is a twisting force that can cause an object to rotate about any axis. For example, when our muscles contract, torque is created that causes rotational movement about our shoulder (e.g., swimming motion) or hip (e.g., biking motion) joints. Torque also makes it possible for bolts to be tightened with wrenches, children to play on see-saws or rockets to tumble out of control.

Torque is defined by how much a **Force** acting on an object causes that object to rotate. The object rotates about an axis (**pivot point**). The force is called 'F,' and the distance between the pivot point and where the force acts is referred to as the **moment arm** (called 'r'). The distance, 'r,' force 'F,' and resultant torque are all vector quantities. Finally, θ is used to measure the angle at which the force was applied.

Instructions

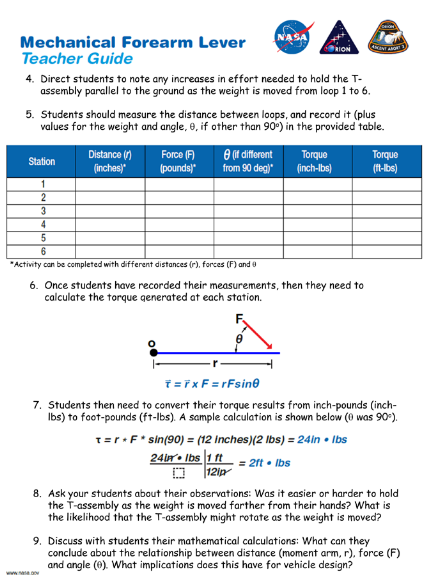
1. Materials needed for this activity include a PVC (polyvinyl chloride) pipe T-assembly or similar apparatus with metal loops regularly spaced apart (as shown in FIGURE 1 below), a 2 lb. hanging weight (or other weight), and a metal S-shaped hook for hanging the weight from the T-assembly loops.
2. Have one student hold the T-assembly while their partner(s) move the 2 lb. weight from the loops closest to the hands to loops farther out (as shown in FIGURE 2 below; θ = 90°).
   Note: In the figures below, loops are marked by red tape and are spaced approximately 6 inches apart.

Figure 1

Figure 2

www.nasa.gov

Mass Properties Instructional Activity for Middle and High School Grades
(Credit: NASA Langley *Orion* FTMO)



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4. Direct students to note any increases in effort needed to hold the T-assembly parallel to the ground as the weight is moved from loop 1 to 6.
5. Students should measure the distance between loops, and record it (plus values for the weight and angle, θ, if other than 90°) in the provided table.

Station	Distance (r) (inches)*	Force (F) (pounds)*	θ (if different from 90 deg)*	Torque (inch-lbs)	Torque (ft-lbs)
1					
2					
3					
4					
5					
6					

*Activity can be completed with different distances (r), forces (F) and θ

6. Once students have recorded their measurements, then they need to calculate the torque generated at each station.

$$\vec{\tau} = \vec{r} \times F = rF\sin\theta$$

7. Students then need to convert their torque results from inch-pounds (inch-lbs) to foot-pounds (ft-lbs). A sample calculation is shown below (θ was 90°).

$$\tau = r * F * \sin(90) = (12\ \text{inches})(2\ \text{lbs}) = 24\text{in} \bullet \text{lbs}$$

$$\frac{24\text{in} \bullet \text{lbs}}{\square}\Big|\frac{1\ \text{ft}}{12\text{in}} = 2\text{ft} \bullet \text{lbs}$$

8. Ask your students about their observations: Was it easier or harder to hold the T-assembly as the weight is moved farther from their hands? What is the likelihood that the T-assembly might rotate as the weight is moved?
9. Discuss with students their mathematical calculations: What can they conclude about the relationship between distance (moment arm, r), force (F) and angle (θ). What implications does this have for vehicle design?

www.nasa.gov

The badge ultimately went through three rounds of peer review before its publication in early July 2018. While the *Orion* Ascent Abort-2 badge received the same stringent appraisal from EPDC Specialists as every other digital badge does, this particular effort benefitted immeasurably from the novel step of soliciting evaluations <u>directly</u> from a NASA technical expert <u>and</u> a public affairs specialist. To the best of anyone's knowledge, this was the first time a NASA digital badge had <u>both</u> outside perspectives blended with EPDC's distinctive instructional and culturally relevant teaching (CRT) expertise. Although there were many instances where this unique collaboration influenced the final product, three representative examples are presented here as illustrations.

As the first round of peer review commenced, it soon became clear that the FTMO mass properties engineer and Langley's *Orion* Public Affairs Specialist may not have been entirely certain of what to expect when they first sought OSTEM's assistance in disseminating their Centennial instructional products to teachers and students. After viewing screen shots of how the badge would look to educators in the EPDC badging system, the *Orion* Public Affairs Specialist replied, "I think this looks great!" before suggesting that ALL of the instructional graphics they had provided be updated, "…so they look more uniform and maybe a little 'snazzier' for lack of a better word?" (Damadeo, personal communication, April 27, 2018). FTMO's mass properties engineer concurred, explaining that the originals had been, "created…by a bunch of engineers…a few days before Centennial" (Cutright, personal communication, April 27, 2018). Although the EPDC badging committee's original plan had been to publish this as one of its five badges for May, Langley's EPDC Specialist recognized the value in adjusting that timeline to meet the "customers'" request so that they would be truly happy with the finished product – "the *Orion* and *SLS* comms [communications] teams will definitely want to promote this!" (Damadeo, personal communication, April 27, 2018). Thus, the EPDC Specialist alerted the badging committee leads of the graphics delay, who were supportive of it (Weiss and Buckner, personal communication, May 1, 2018).

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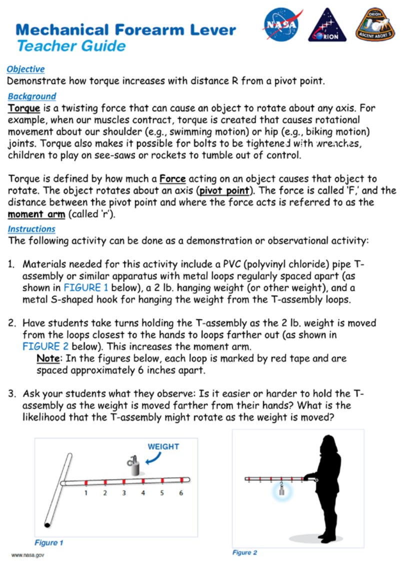

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Torque is defined by how much a **Force** acting on an object causes that object to rotate. The object rotates about an axis (**pivot point**). The force is called 'F,' and the distance between the pivot point and where the force acts is referred to as the **moment arm** (called 'r').

Instructions
The following activity can be done as a demonstration or observational activity:

1. Materials needed for this activity include a PVC (polyvinyl chloride) pipe T-assembly or similar apparatus with metal loops regularly spaced apart (as shown in FIGURE 1 below), a 2 lb. hanging weight (or other weight), and a metal S-shaped hook for hanging the weight from the T-assembly loops.

2. Have students take turns holding the T-assembly as the 2 lb. weight is moved from the loops closest to the hands to loops farther out (as shown in FIGURE 2 below). This increases the moment arm.
   Note: In the figures below, each loop is marked by red tape and are spaced approximately 6 inches apart.

3. Ask your students what they observe: Is it easier or harder to hold the T-assembly as the weight is moved farther from their hands? What is the likelihood that the T-assembly might rotate as the weight is moved?

Mass Properties Instructional Activity for Elementary Grades (Credit: NASA Langley *Orion* FTMO)

Space Shuttle *Endeavour* at the Kennedy Space Center (Credit: NASA)

With the badge's primary focus on technical engineering content (i.e., mass properties), Langley's EPDC Specialist sought to also incorporate instructional activities for educators who wished to present the complex mathematics involved in a format that could be easily grasped by their younger students. This would broaden the badge's potential audience, especially to elementary-grade teachers who may not necessarily be as familiar with trigonometric calculations. Based on informal feedback from EPDC's technical manager, the EPDC Specialist created an alternate version of the mechanical forearm lever activity (Blystone, personal communication, May 23, 2018). This alternative instead asked students to qualitatively (rather than quantitatively) describe what they had observed with the T-assembly as the two-pound weight was moved further away from their hands. Additionally, drawing upon some of EPDC's best practices for culturally relevant teaching (CRT), Langley's EPDC Specialist designed a brand new interdisciplinary activity that would give educators an opportunity to integrate social studies, art and STEM subjects (Garcia, Ortiz, Smith and Torres, personal communication, November 6, 2017). For the activity, a badge earner selects a real or mythical object, which may have cultural significance, that does have mass properties (e.g., mass, weight, volume and center of gravity). They then create an artistic representation of it and qualitatively describe the object's mass properties in a 150-200 word summary. The EPDC Specialist selected a picture depicting the Hindu and Native American beliefs that Mother Earth piggybacks through the Universe on elephants and/or a giant cosmic turtle, similar to the Space Shuttle orbiters piggybacking on a modified Boeing 747 plane. During the peer review process, EPDC's Field Coordinator recommended an authenticity check in order to ensure that "the examples are accurate and capture these alternate beliefs respectfully" (Duclos, personal communication, May 9, 2018). Accordingly, Langley's EPDC Specialist invited a Texas State University-based EPDC Specialist to guest review the badge, paying particular attention to the interdisciplinary, cultural activity. He replied:

> "The description and info. looks good. My only recommendation would be to indicate that the myth of

Photo credit: 'The World Turtle' by Chibineo

> Mother Earth riding on the back of a turtle is a creation story believed by certain Native American tribes, namely the Iroquois" (Garcia, personal communication, May 23, 2018).

The unique CRT application and activity captured the attention of the FTMO mass properties engineer, who remarked:

> "Option #3 and the elephant/turtle/earth picture? Seriously, where did this come from, can I use the graphic? I learned something new and makes me want to know more! Great spin on mass properties too… I may challenge some senior SAWE leaders to answer the CG [center of gravity] question on that one!" (Cutright, personal communication, April 27, 2018).

Lastly, as the digital badge's review process progressed, the Langley FTMO mass properties engineer increasingly advocated for items that would not only benefit the *Orion* Ascent Abort-2 test, but which would also be of keen interest to the Society of Allied Weight Engineers [SAWE], the international professional organization for mass properties engineering. Langley's EPDC Specialist tentatively proposed naming the new badge '*Finding Balance: Rocket Mass Properties*,' which fit the badging system's character limit. When she first saw it, the FTMO mass properties engineer remarked:

> "Love the title (I know I'm biased), but I promise the…(SAWE) is going to be very impressed the words 'mass properties' made it into some STEM curriculum" (Cutright, personal communication, April 27, 2018).

However, Langley's *Orion* Public Affairs Specialist caught the 'rocket' misnomer, noting that, "*Orion* isn't a rocket/launch vehicle" (Damadeo, personal communication, May 25, 2018). The FTMO mass properties engineer agreed, confirming that the badge title should be changed to more accurately reflect what *Orion* is (i.e., a spacecraft). With the badging system's character limitation, this presented a minor challenge in that the words "mass properties" had to survive, if at all possible:

> "…but I will also say you are going to get a lot of traction with Society of Allied Weight Engineers (SAWE) professional society if you include the words 'mass properties' in the title (this would very seriously just make their day/year/ decade?)…" (Cutright, personal communication, July 2, 2018).

After working through various iterations, Langley's EPDC Specialist proposed '*Balancing Act: Spacecraft Mass Properties*;' all collaborators accepted the change.

As the badge title evolved, the FTMO engineer made one last plug to incorporate SAWE resources into the final product. Langley's EPDC Specialist had previously planned to include career information for educators who might have students interested in engineering, but she could only find one video about flight test articles that briefly alluded to engineering careers. As the EPDC Field Coordinator noted, "Okay, I just looked at the Instructions; where does the career info come into play?" (Duclos, personal communication, June 22, 2018). Fortunately, persistence on the part of Langley's FTMO mass properties engineer resolved the badge's career/workforce development dilemma:

> "Last minute attempt at a plug for SAWE: …Consider adding…Click on <pick an SAWE website of your choice> …to hear about how a professional society of mass properties engineers from around the world and from different cultures and organizations work together to share information on similar mass properties challenges" (Cutright, personal communication, July 2, 2018).

Options for "SAWE website of your choice" included links to the aforementioned SAWE podcasts that the society had recorded in 2008 in order to aid its recruiting efforts. Langley's EPDC Specialist promptly inserted the SAWE career information before notifying all Langley-based collaborators:

> "I have attached a PDF…of the final version so you

can take one last look before it goes live. ...Hopefully, we've made SAWE's day/year/decade (century? ☺) by incorporating BOTH "mass properties" in the badge's title and links to ALL…suggested SAWE resources [I needed to beef up the badge's workforce connections…and those SAWE websites fit the bill perfectly]. …Unless I hear otherwise, I will publish tomorrow morning and provide…links for the Orion comms plan. Here we go! ☺" (Weiss, personal communication, July 5, 2018).

The *Balancing Act-Spacecraft Mass Properties* badge went live on July 6, 2018.

FUTURE DIRECTIONS

Although the *Orion* and *SLS* comms teams requested that full-scale marketing of the *Balancing Act-Spacecraft Mass Properties* digital badge commence in late spring 2019 (closer to the time of the Ascent Abort-2 test itself in the summer), its development and publication has led to several smaller publicity efforts. Immediately after its release, the badge, along with a standalone video interview with the FTMO mass properties engineer, became part of a larger flipped classroom unit that was introduced to a group of high school mathematics teachers attending a two-week professional development institute at the Langley Research Center (Smith, personal communication, July 18, 2018). Beyond that, the pipe cleaner/craft stick modeling activity for *Orion*'s Launch Abort System has indeed taken its place in OSTEM's rotation of instructional kits for face-to-face events (e.g., Langley Youth Day, Naval Air Station Oceana Air Show, etc.), as originally envisioned by the Education Specialist Lead (Brush, personal communication, January 25, 2018). Presenters even demonstrated the activity at the 2019 Space Exploration Educators Conference (SEEC) in Houston, TX (Smith, personal communication, February 11, 2019). In the months to come, Langley's EPDC Specialist plans to broadcast several webinars to advertise the badge's


Photo credit: NASA Langley

availability to K-12 teachers nationwide in support of the public relations strategy devised by the *Orion* Communications team for AA-2.

The unique collaboration between Langley education specialists and researchers that produced *Balancing Act-Spacecraft Mass Properties* attracted the attention of both OSTEM and Langley Research Center leadership. This partnership demonstrated what could be possible when two constituencies, which have not traditionally collaborated much if at all, worked together to produce educational products. The development process served as an early and indirect template for the STEM Education Accountability Project (SEAP) Pilot Opportunity for Centers; what would later become the Next Gen STEM Pilot Project, which includes themes for aeronautics (Small Steps, Giant Leaps), deep-space human exploration (From Moon to Mars), and NASA's Commercial Crew Program (CCP) (Cherry, personal communication, May 23, 2018). The collaboration's early success even landed it in the Center's annual report (NASA Langley Research Center, 2018). Depending on how the Next Gen STEM Pilot Project unfolds over the coming months, the novel customer-service business model approach between education specialists and subject matter experts that produced NASA STEM EPDC's *Balancing Act-Spacecraft Mass Properties* digital badge may become a foundation for OSTEM's work in the future.

Successful production of two OSTEM educational products related to Ascent Abort-2 (i.e., the standalone video interview for flipped classrooms and the educator professional development badge), which incorporated Society of Allied Weight Engineers (SAWE) resources, led to an unexpected invitation from the professional organization. Based on a recommendation from the FTMO mass properties engineer, the SAWE Technical Papers Lead reached out to Langley's EPDC and Education Specialists to inquire whether they might be able to present at SAWE's Hampton Roads Chapter Coastal Virginia Conference later in the fall (Cerro, personal communication, August 16, 2018). Designed for a highly technical audience, the regional conference affords SAWE members the opportunity to network with each other

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Photo credit: Society of Allied Weight Engineers [SAWE]

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as well as to hear presentations on mass properties research from academic, government and industrial projects. In the context of the forthcoming AA-2 test and SAWE leadership's continuing efforts to leverage educational outreach and student recruitment in support of their mission, the Society's President, Vice President-Technical Director, and Vice President-Academic Affairs were all "*very* interested in the NASA mass properties badge presentation that you are presenting at the regional conference…" (Gerren, personal communication, August 16, 2018). Langley's EPDC and Education Specialists ultimately discussed the changing education landscape and 21st-century undergraduate engineering education before presenting their created educational products, complete with a hands-on demonstration of the pipe cleaner/craft stick modeling activity of the *Orion* Launch Abort System (Weiss & Smith, 2018). The concurrent session was so well-received that SAWE leadership inquired whether the Specialists would be able to repeat it:

"Several folks had told me how great it was to have your and Anne's presentation at the Regional [Conference], and of course the follow up question is, would you like to do it again in May [2019] at the International Meeting. …If you want to go so far as to provide a paper on the topic, that would be great. (Cerro, personal communication, December 12, 2018).

Langley's EPDC and Education Specialists promptly accepted the offer with submission of an abstract; a technical paper is forthcoming and the presentation will be made at the 78th SAWE International Conference on Mass Properties Engineering in Norfolk, Virginia.

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For more information about NASA STEM EPDC, please visit txstate-epdc.net.

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References

Altheide, D.L., & Schneider, J.W. (2017). *Qualitative media analysis*. 2nd ed. Thousand Oaks, CA: Sage.

Boston Consulting Group [BCG]. (2015). Teachers know best: Teachers' views on professional development. Retrieved from http://k12education.gatesfoundation.org/resource/teachers-know-best-teachers-views-on-professional-development/.

Bowen, G.A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal, 9*(2), 27-40.

Bowen, W.G. (2013). *Higher education in the digital age*. Princeton, NJ: Princeton University Press.

Boze, W. (2018). Everything you wanted to know about mass properties engineering but were afraid to ask. Paper presented at the Society of Allied Weight Engineers [SAWE] Hampton Roads Fall Regional Conference, Norfolk, VA.

Collis, A., & Halverson, R. (2009). *Rethinking education in the age of technology*. New York, NY: Teachers College Press.

Creswell, J.W. (2013). *Qualitative inquiry and research design*. 3rd ed. Thousand Oaks, CA: Sage.

Cutright, A. (2018). Ascent Abort-2 integrated flight test vehicle: How mass properties are used to manage flight test objectives. Paper presented at the Society of Allied Weight Engineers [SAWE] Hampton Roads Fall Regional Conference, Norfolk, VA.

Dawley, L., Rice. K., and Hinck, G. (2010). Going virtual! 2010: The status of professional development and unique needs of K-12 online teachers. Retrieved from https://edtech.boisestate.edu/goingvirtual/goingvirtual3.pdf.

Gamrat, C., Zimmerman, H.T., Dudek, J., & Peck, K. (2014). Personalized workplace learning: An exploratory study on digital badging within a teacher professional development program. *British Journal of Educational Technology, 45*(6), 1136-1148.

Lattuca, L., Terenzini, P., Knight, D., & Ro, H. (2014). 2020 vision: Progress in preparing the engineer of the future. Retrieved from https://www.researchgate.net/publication/280230797_2020_Vision_Progress_in_Preparing_the_Engineer_of_the_Future

Martinez Ortiz, A., Weis, J., & Merritt, J. (2018). Micro-certification as professional development for STEM educators: The NASA STEM EPDC badging system (*STEM Research White Paper Series*, Vol. 2, No. 3). Texas State University: LBJ Institute for STEM Education and Research.

McDonald, S. (2017). At Centennial Open House, NASA Langley's past, present and future shined. Retrieved from https://www.nasa.gov/feature/langley/at-centennial-open-house-nasa-langley-s-past-present-and-future-shined-brightly.

National Academy of Engineering [NAE]. (2004). The engineer of 2020. Washington, DC: The National Academies Press.

NASA eClips/Launchpad. (2009). Flight test articles. Retrieved from https://www.youtube.com/watch?v=cPgxMYJSIK4.
NASA eClips/Launchpad. (2009). Mass properties. Retrieved from https://www.youtube.com/watch?v=fr2KgV9mBDQ.
NASA EDGE. (2010a). Orion launch abort system (part 1 of 3). Retrieved from https://www.youtube.com/watch?v=stTOKY4tQvs.
NASA EDGE. (2010b). Orion launch abort system (part 2 of 3). Retrieved from https://www.youtube.com/watch?v=JijDrHNaQfc.
NASA EDGE. (2010c). Orion launch abort system (part 3 of 3). Retrieved from https://www.youtube.com/watch?v=kmn-INpXx2I&t=0s&list=PLBD9ED1A7703328C2&index=3.
NASA Langley Research Center. (2018). Ideas on the rise: 2018 annual report. Retrieved from https://issuu.com/nasalangley/docs/2018_nasa_langley_annual_report?e=30497210/66068850.
National Aeronautics and Space Administration [NASA]. (2017). Orion spacecraft overview. Retrieved from https://www.nasa.gov/sites/default/files/617409main_orion_overview_fs_33012.pdf.
Rosenberg, M. (2018). Baby boom: The population baby boom of 1946-1964 in the United States. Retrieved from https://www.thoughtco.com/baby-boom-overview-1435458.
Society of Allied Weight Engineers [SAWE]. (2008). NASA's Amanda Cutright: Youth and leadership. Retrieved from https://www.sawe.org/podcasts/amandacutright.
Space Frontier Foundation. (2012). NewSpace 2012 Conference Program. Retrieved from https://www.scribd.com/document/230157325/NewSpace-2012-Program.
Stake, R. (2000). Case studies. In N.K. Denzen and Y.S. Lincoln (Eds.), *Handbook of qualitative research* (2nd edition, pp. 435-454). Thousand Oaks, CA: Sage.
Terenzini, P., Lattuca, L., Kremer, G., Plumb, C., & Trautvetter, L. (2008). Preparing the engineers of 2020: Emerging evidence from six exemplary colleges and universities. Paper presented at the 38th ASEE/IEEE Frontiers in Education Conference, Saratoga Springs, NY.
U.S. Department of Education Office of Educational Technology. (2017). Reimagining the role of technology in education: 2017 National education technology plan update. Retrieved from https://tech.ed.gov/files/2017/01/NETP17.pdf.
Vitug, E. (2017). Get inspired at NASA Langley's Open House. Retrieved from https://www.nasa.gov/langley/feature/get-inspired-at-nasa-langley-open-house.
Weiss, A., & Smith, R. (2018). Educator professional development teacher resource training: *Balancing Act-Spacecraft Mass Properties*. Paper presented at the Society of Allied Weight Engineers [SAWE] Hampton Roads Fall Regional Conference, Norfolk, VA.
Wiley, D., Williams, L., DeMarte, D., & Hilton, J. (2016). The Tidewater Z-Degree and the INTRO model for sustaining OER adoption. *Educational Policy Analysis Archives, 23*(41), 1-15.
Yin, R.K. (2009). *Case study research: Design and method*. 4th ed. Thousand Oaks, CA: Sage.