FEMSTEAM MYSTERIES: STEAM SCENARIO TEMPLATE

Title

Margaret Hamilton Saves the Moon Landing

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Summary

The scenario aims to raise student awareness of the risks and difficulties faced by NASA's Apollo space program and the vital contribution of female software engineer Margaret Hamilton and her team. Its secondary aims are to challenge stereotypes inherent in the roles of men and women in Computer Science and Software Engineering and to present male and female students with a compelling role model from the early years of computing, where formerly impossible feats, such as landing a craft on the moon, were quickly becoming possible.

The end product of this scenario is for students to create an arts-based product telling the story of the dangers involved in the lunar missions of the 1960s, where the technology could never be truly tested in its working environment without the risk of complications and even fatalities. The mitigation of these potential failures could only be achieved through the efforts of the most competent engineers, and success and failure, life and death, was constantly in their hands. The rigorous planning and design of Hamilton's Apollo Guidance Computer flight software ultimately made the difference between Armstrong's "One small step for man, one giant leap for mankind," and the complete failure of the mission. Students will capture the dramatic contribution of Hamilton, against the background of the extreme danger and complexity of the Apollo space program, in a moment in history that captured the attention of the world, having learned of the contribution of this remarkable female software engineer and the real-world, and off-world, importance of dependable technology and its designers.

The scenario consists of these activities:

1. *Planning a speech based on the speech, In Case of Moon Disaster, written by Presidential Speechwriter William Safire.*
2. *A play through of the FemSTEAM Mysteries game, for students to learn of the contribution of more contemporary female scientists.*
3. *Learning of the engineering challenges that early space missions encountered, along with the danger and losses they caused, and how they were handled and mitigated.*
4. *Calculating the energy required to launch an Apollo Command Module into space and out of the Earth's gravitational field, using ballistic calculations.*
5. *Learning about the Apollo Guidance computer: its physical structure, programming, and mission-critical nature.*
6. *Learning about Margaret Hamilton and her team.*
7. *A presentation of the story of Apollo 11, the first successful lunar mission, focusing on the many difficulties faced during the mission, especially how Hamilton's team's flight software was able to handle the interrupt overload that would have otherwise prevented Armstrong and Aldrin from landing on the moon.*
8. *Creating an arts-based product, such as a comic strip, drama play, or speech, to capture the story of the Apollo 11 moon landing and Hamilton's vital contribution to saving the mission.*

The expected STEAM learning outcomes are:

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Subjects

- English: The Apollo 11 lunar mission was the first attempt at landing on the moon and was accompanied by two speeches: one to celebrate a successful landing and recovery of the astronauts, and another entitled *In Case of Moon Disaster*, to be read if the astronauts died on the moon. Students will study these speeches and understand how to write a compelling speech.
- Physics/Maths: Studying and calculating the physics involved in launching a heavy spacecraft into the sky and out of the Earth's gravitational pull in a survivable and repeatable way.
- Computing: Cover the realities of the intricately designed hardware and software of the Apollo Guidance Computer, including the contribution of Hamilton and her team, and the dramatic story of the cascading hardware errors that nearly caused the astronauts to abort the lunar landing.
- Art/Drama: Produce a product (such as a comic strip or short play) to tell the story, or part of the story, of the Apollo 11 mission, with a focus on the work of Hamilton.

Real-life questions

For this scenario, students will be responding to the following questions:

- *Are the role models from 60 years ago still relevant to us today?*
- *What female role models existed in STEAM in the 1960s who were valued then but are forgotten today?*
- *Is it possible for us to make such large contributions to the world today through careers in STEAM?*
- *What would have happened if the Apollo Guidance Computer had not been able to recover from the hardware issues from its sensors?*
- *What is the important contribution of Margaret Hamilton in modern history?*
- *What part of the story of Apollo 11 do you want to highlight?*
- *How did this activity help you to understand the role of women in 1960s STEAM and the 'space race' better?*
- *How do words create an effective atmosphere to help an audience understand the significance of an event?*
- *How did the activity help me to break the stereotypes around STEAM people?*

Aims of the scenario

The scenario aims:

- *To raise awareness of the forgotten contributions to human achievement and exploration.*
- *To demonstrate the exciting range of real-world careers and activities open to qualified STEAM practitioners.*
- *To highlight the achievements of a female software engineer.*
- *To develop an understanding of the importance of excellence in one's learning, training, and career and daily work therein.*
- *To inspire artistic creativity in telling a dramatic, multi-faceted, multi-disciplinary story in an effective and clear way.*

Connection to STEAM careers

Direct connection to Computer Science, Physics, and Engineering, and the vital importance of excellence in such careers. Indirect connection to English (speechwriting) and its importance in publicly announcing complicated scientific achievements for a mass audience. Indirect connection to Art (production of comic, poster, or other story-telling artwork), demonstrating its role in human appreciation of historic moments.

Age of students

12-13 years old

Time

Preparation time: 1 hour

Teaching time:

- **Preparation: 1 hour**
- **English: 1 hour 30 minutes**
- **Science (Physics) & Mathematics: 1 hour 30 minutes**
- **Computer Science: 1 hour 30 minutes**
- **Art: 1 hour 30 minutes**

Assessment time: 1 hour

Teaching resources (material & technological tools)

Materials:

Art supplies, in addition to normal lesson materials and equipment that is commonly available.

Online tools:

FemSTEAM Mysteries game.

Website: In Case of Moon Disaster.

Research materials for the Apollo Guidance Computer, including the work of Margaret Hamilton in the AGC project.

Research materials for the Apollo 11 mission.

Online video links of both speeches.

21st century skills

This educational scenario will enhance among the students the following skills, defined as 21st century skills:

- Collaborative work in gender-diverse teams to tell the story of the Apollo 11 mission and Hamilton's contribution.
- Science, technology and engineering understanding and competence will be developed through considering the engineering challenges and ballistic requirements of the launch and associated hardware.
- Digital competence will be enhanced through use of search engines and by looking at the design of an early digital computer with a focus on durability and absolute reliability.
- Gender role awareness will be developed through learning of how female engineers were valued and celebrated even in the 1960s, by learning of the achievements and later successes of a notable example (Margaret Hamilton).

Teaching approaches and learning strategies/theories

List and justify the main teaching pedagogies and strategies you will apply and their relationship to the FemSTEAM Mysteries role-model game-based approach to gender equality in STEAM.

Educational scenario

Name of activity	Procedure	Time
1st Lesson: ENGLISH LESSON ON NIXON SPEECHES		
Brainstorming and discussion	Read or show the speech *IN CASE OF MOON DISASTER* (see appendix for full text and video link). Introduce speech writing, planning a speech and writing a successful speech. *A helpful guide can be found here:* https://www.bbc.co.uk/bitesize/topics/zv7fqp3/articles/z4w96v4 *Alternatively, a video explanation can be found here:* https://www.youtube.com/watch?v=oV1h7n0HcTE Look at examples of language that shows danger and how to create effect using rhetorical devices. *The following examples could also be useful:* *Reference to death of soviet cosmonauts in the Soyuz 11 Disaster and the deaths of American astronauts in Apollo 1 ground test.* *Safire's full speech, can be found on this page about a related Soviet disaster (which occurred for far less excusable reasons):* *Cosmonaut Crashed Into Earth 'Crying In Rage' : Krulwich Wonders... : NPR* *Note: The accuracy of the above story has been disputed, and several facts appear to be inaccurate, though the death of the astronaut definitely occurred.* *Nixon's inspiring speech as the Apollo 11 astronauts start their mission (starting at 1:57):*	90'

Name of activity	Procedure	Time
	https://www.youtube.com/watch?v=JoTAEi5rolM *Telephone conversation with astronauts on Apollo 11:* *https://www.americanrhetoric.com/speeches/richardnixonapollo11call.htm* *Deepfake speech on possible disaster by Nixon (at 3:37):* In Event of Moon Disaster TASK: Create a plan for your speech and a powerful introduction implementing all the ideas used and taught about speech writing. Once you have a satisfactory plan, write your speech using the skills we learned today.	
2nd Lesson: PHYSICS: Ballistic considerations and calculations for the Apollo 11 launch		
STEAM: **Science (Physics)** **Mathematics**	*Classs discussion on the Saturn V rocket and the amount of thrust, danger, and physical forces involved in propelling the 4.5-ton Apollo Command module, and its astronauts, into space.* *Presentation of ballistic equations involved in sending a rocket, and its payload, into space.* *Students calculate the quantity of fuel required to send the Saturn V and its payload into space.* *Students calculate the energy released by the fuel, and the degree of destruction that would occur if the rocket were to fail and explode.* *Teacher displays a compilation of rocket explosions to give a visual demonstration of the power and danger involved:* *https://www.youtube.com/watch?v=ZI-f_M9aEck*	45’
Learning products	*Ballistic calculations of the energy requirements and forces involved in the Apollo 11 launches.*	
3rd Lesson: The Apollo Guidance Computer and Margaret Hamilton		
STEAM: Computer Science	Students play the FemSTEAM Mysteries game, looking at the achievements and contributions of some prominent female scientists. Discussion on the Apollo Guidance Computer, its role, and its specifications (along with the technological limitations they	30’ 15’

Name of activity	Procedure	Time
	had to overcome). Students fill out a gapped handout during the presentation. Students research what went wrong with the Apollo 11 mission. Several things came up, including a broken circuit breaker nearly stranding the astronauts on the moon, but ensure students eventually focus on the issues with the radar sensor flooding the AGC with interrupts. Presentation on the work of Margaret Hamilton and her team, and how the robust software of the AGC and the excellent software engineers who both created *and* understood it, enabled the mission to continue on to success. Students complete activity sheet *The excellent AGC software and its designers*.	 10’ 25’ 10’
Learning products	WORKSHEET: The job and specifications of the AGC RESEARCH: What went wrong in the Apollo 11 mission that caused them to almost abort the moon landing? ACTIVITY: The excellent AGC software and its designers	
4th Lesson: ART: Producing a comic strip rendition of a moment in the Apollo 11 mission		
STEAM: Art	Students collaborate in creating a comic panel or drama sketch, to show a specific moment or sequence in the story of Apollo 11, either highlighting the dangers involved in the mission, the complexity of space exploration, the success of the mission, or the moment when the Apollo Guidance Computer started giving error messages.	90’
Learning products	*The comic/script.*	

Assessment
Initial assessment

Scripts written during first lesson, in terms of whether they capture the dramatic nature of the dangerous and technologically untested missions into the unknown.

Informal assessment through conversation during lesson, to ascertain the degree to which students understand the impact of the work of Hamilton and her team.

Quality and content of comics produced

Formative evaluation

- *Students write a speech using powerful emotive rhetoric to show and create sense of danger or being at risk.*
- *Students demonstrate understanding, both verbally and through calculations, of the ballistic forces and fuel requirements for the Apollo 11 launch.*
- *Written and verbal demonstrations of understanding of the extreme complexity of space exploration, and the dangers associated with it.*
- *Answers produced for WORKSHEET: The excellent AGC software and its designers.*

Final assessment

Assessment of the evolution of their beliefs, answering the questions:

- *What have you learned about the complexity and danger of space travel in its earliest years?*
- *What real-life applications of STEAM have you seen in this story that were critical for the success of the Apollo 11 mission?*
- *What role models have been presented to you in this project?*
- *Do you see yourself possibly working toward a career in one of the areas highlighted in this project?*

Student feedback

The students are expected to provide feedback on how the lessons were received and implemented.

- Students enjoyed making the comic strip
- Students found the presentation interesting, especially with the technological limitations faced by the designers of the AGC. Predictably, the more technically-inclined students were more likely to enjoy this part.
- Students understood the contribution made by Margaret Hamilton to the Apollo 11 mission and to modern Computer Science in general.
- Students understood the point of the project well; none reported being confused in this area.

Teacher feedback

The teachers are expected to provide feedback on how the lessons were received and implemented.

- The Maths task ran well and was simple enough that the classes were able to complete it in less time than had been allocated in the plan.
- The speech-writing task was satisfying to teach and well-received by students. Most students produced a high-quality end product.
- The presentation was well-understood, but the tasks on the AGC and Margaret Hamilton ended up being rushed due to time constraints, and the most important task (the work of Margaret Hamilton) had to be covered through class discussion rather than by completing the written task. It would have been better to have delayed this part of the project somewhat in favour of having the full amount of allocated time.

Appendices

Here, a thorough and complete list of worksheets and other materials used in the scenario should be provided. These resources should be cited as Annexes and they can be further cited within the learning scenario.

Cited and included below:

1. The job and specifications of the AGC
2. The excellent AGC software and its designers
3. IN EVENT OF MOON DISASTER
4. Ballistic calculations worksheet

The job and specifications of the AGC

1. **Why did the astronauts need the Apollo Guidance Computer (AGC)?**

2. **What was the AGC used for during the mission?**

3. **The AGC couldn't use memory chips, hard disks, or magnetic tape. What did it use to store its data in RAM and ROM?**

4. **How did the astronauts interact with the AGC? (Describe its user interface)**

The excellent AGC software and its designers

Who was Margaret Hamilton?

Describe her team and what they did for the Apollo space program

What did she and her team do to make sure the Apollo Guidance Computer would not let the astronauts down when they needed it the most?

What problem did the astronauts face that meant they could not land on the moon unless the computer could recover from the issue they had? (Tell the story of this part of the mission)

How did Mission Control know whether they could continue the mission (and land the astronauts on the moon) or not? Who was there from Hamilton's team, and what did he do?

Why is it important to design reliable software for important safety applications like this?

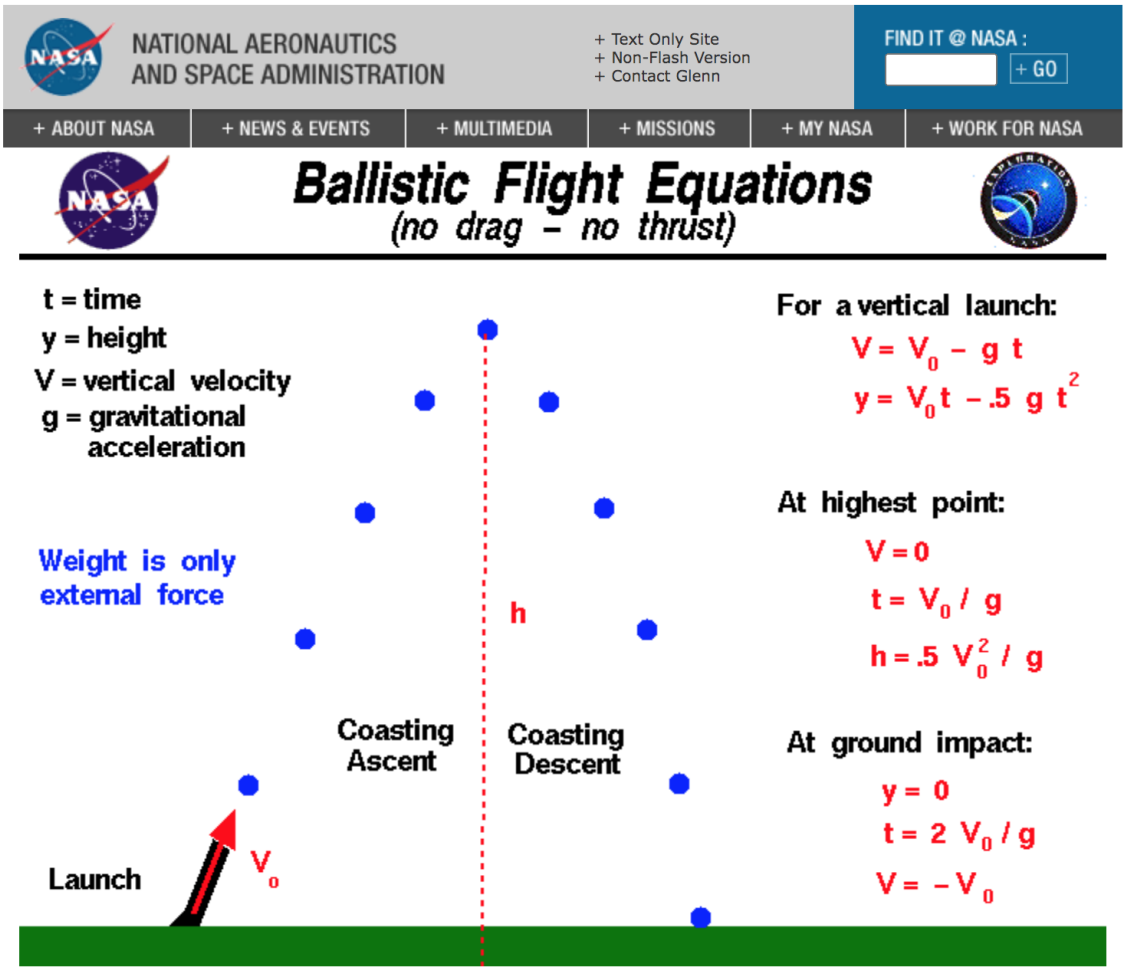
IN EVENT OF MOON DISASTER, read by Benedict Cumberbatch

https://www.youtube.com/watch?v=VfZUkOIk5z0

Transcript:
To: H. R. Haldeman
From: Bill Safire
July 18, 1969.
————————————————————-
IN EVENT OF MOON DISASTER:
Fate has ordained that the men who went to the moon to explore in peace will stay on the moon to rest in peace.
These brave men, Neil Armstrong and Edwin Aldrin, know that there is no hope for their recovery. But they also know that there is hope for mankind in their sacrifice.
These two men are laying down their lives in mankind's most noble goal: the search for truth and understanding.
They will be mourned by their families and friends; they will be mourned by the nation; they will be mourned by the people of the world; they will be mourned by a Mother Earth that dared send two of her sons into the unknown.
In their exploration, they stirred the people of the world to feel as one; in their sacrifice, they bind more tightly the brotherhood of man.
In ancient days, men looked at the stars and saw their heroes in the constellations. In modern times, we do much the same, but our heroes are epic men of flesh and blood.
Others will follow, and surely find their way home. Man's search will not be denied. But these men were the first, and they will remain the foremost in our hearts.
For every human being who looks up at the moon in the nights to come will know that there is some corner of another world that is forever mankind.
PRIOR TO THE PRESIDENT'S STATEMENT:
The President should telephone each of the widows-to-be.
AFTER THE PRESIDENT'S STATEMENT, AT THE POINT WHEN NASA ENDS COMMUNICATIONS WITH THE MEN:
A clergyman should adopt the same procedure as a burial at sea, commending their souls to "the deepest of the deep," concluding with the Lord's Prayer.
Compare with Nixon's call to the Astronauts on the moon:

https://www.youtube.com/watch?v=m08Q5Os1DWI

Margaret Hamilton saves the moon landing



VIDEO

Rocket trajectory

https://www.youtube.com/watch?v=cuFd7QaG6Rs

Exercise 1: Substituting into a formula

a) For the formula of a vertical launch $\boldsymbol{y = V_0 t - 0.5 g t^2}$

b) Find the value of y if $g = 10m/s^2$, $t = 4s$, $V_0 = 50m/s$

Exercise 2: Converting units

The maximum velocity of Apollo 11 was 25000m/h.

Convert this velocity to km/h

(1mile=1.60934km)

Fun fact!! It took 4 days, 6 hours and 45 minutes for Apollo 11 to reach the moon.

Neil Armstrong and Buzz Aldrin reportedly ate **beef with vegetables, pork and potatoes and bacon and apple sauce**. All of these meals had to be re-hydrated in a packet and they were all specially labelled for each day.