Hypersonics STEM Curriculum

How Fast is Hypersonic?

Grade	Time	Subject Area	Key Concepts
3	60 min	Physical Science	Speed Speed of sound Number lines

Lesson Overview

In this lesson, students will compare the speed of 12 different objects to develop an understanding of the magnitude of supersonic and hypersonic speeds relative to the speeds of objects they may be familiar with from their everyday life.

This lesson follows a 5E lesson format. The different E's can be done together or as separate lessons. Additionally, the lesson offers reflection/discussion questions with each E. These are provided on the Reflecting: How Fast is Hypersonic handout and can be used as writing prompts or as discussion questions.

NGSS & CCSS Standards

3-PS2-2 Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

CCSS.MATH.CONTENT.3.NBT.A.1 Use place value understanding to round whole numbers to the nearest 10 or 100.

Learning Objectives

By the end of this lesson, students will be able to:

- Compare and predict the magnitude of the speeds of a variety of objects.
- Explain the difference between supersonic and hypersonic speeds.
- Label different sections of a number line.
- Plot the speeds of various objects on the number line with axis major units of 100 m/s.

Essential/Overarching Question

How fast is a hypersonic?

Key Vocabulary

Speed – the rate at which an object is moving. Speed is calculated by dividing the distance travelled by the time it took to travel that distance.

Speed of Sound – the rate at which sound moves through a medium. The speed of sound depends on both the density and the temperature of the medium. The speed of sound through air at 20° C (68° F) at sea level is 343 m/s (767 mph).

Mach – the ratio of the speed of an object to the speed of sound or how many times the speed of sound an object is moving. It is often followed by a number indicating the ratio; for example: Mach 1 is the speed of sound, Mach 2 is twice the speed of sound, Mach 5 is five times the speed of sound.

Sonic – speeds equal to the speed of sound (Mach 1).

Subsonic – speeds smaller than the speed of sound (less than Mach 1).

Transonic – speeds near (Mach 0.8-1.2) the speed of sound where drag is highest (e.g. sound barrier).

Supersonic – speeds greater than the speed of sound (Mach 1 and greater).

Hypersonic – speeds greater than five times the speed of sound (Mach 5 and greater).

Fluid – a substance with no fixed shape; a liquid, gas, or plasma. A substance that flows when an external force is applied to it.

Flow – the motion of a fluid (liquid, gas, or plasma) when it experiences unbalanced forces.

Science Concepts Overview

Different objects move at different speeds. With such a large possible range of object speeds, it can sometimes be hard to compare. In many cases, we compare the speed of an object to the speed of sound. The speed of sound tells you how fast a sound wave travels from its source to its receiver. The speed of sound depends on what medium the sound wave is traveling through (air, water, metal, etc.). It varies directly with both the density of the medium and temperature. The speed of sound of air at 20° C (68° F) is 343 m/s (767 mph).

When we compare the speed of an object to the speed of sound, we do so with a ratio called the Mach number. The Mach number is calculated by dividing the speed of an object by the speed of sound. And the Mach number can be a whole number (Mach 3) or a decimal (Mach 0.6). Additionally, we categorize speeds by the size of their Mach number. Speeds less than Mach 1 are subsonic. Speeds greater than Mach 1 are supersonic. And speeds greater than Mach 5 are hypersonic.

Materials List

- ☐ Reflecting: How Fast is Hypersonic handout (one per student)
- ☐ Object Speed Card Sort handout (one per grouping of students)
- ☐ Scissors (one per grouping of students)
- ☐ Tape or glue (one per grouping of students)

- ☐ Object Speed Number Line handout (one per grouping of students)
- ☐ Writing utensil (students may want to use different colors when labeling)

Lesson Preparation

Prior to the lesson, the instructor should decide how they will group their students for the various parts of the lesson. Based on those groupings, they will need to make copies of the following handouts: Reflecting: How Fast is Hypersonics, Object Speed Card Sort, and Object Speed Number Line.

Creating and working with the Hypersonics Number Line takes a long stretch of space. This would be a great lesson to do in the hallway, gymnasium, cafeteria, outside, or on the classroom floor.

Safety

There are no additional safety concerns beyond normal classroom procedures for this lesson.

Procedure

Engage (5 minutes)

1. Present the following three question to students as a think, pair, share:
    - What is the fastest object you have seen?
    - What is the fastest way you have traveled?
    - What is the fastest object you have heard about?
    - How fast do you think those objects were going?
2. Give students up to 1 minute to think about and/or write out their answer to the engage questions on the Reflecting: How Fast is Hypersonic? handout.
3. Have students pair up and take 1-2 minutes to compare their answers.
4. Once students have shared with their partner, take a few minutes to share out as a class.
5. As part of the discussion, you could ask the students:
    - How much faster do you think we could travel?
    - Do you think any of the objects we discussed moved at supersonic or hypersonic speeds? Which ones?

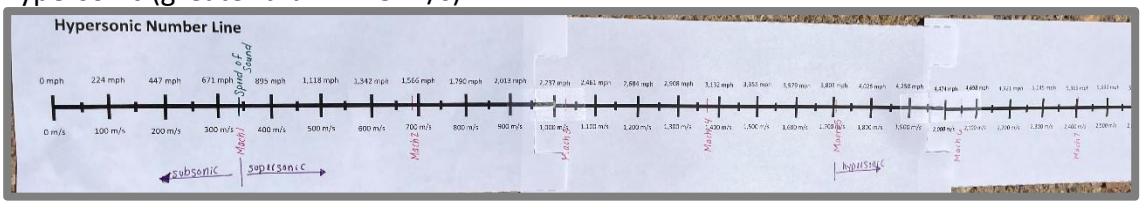
Explore (15 minutes)

6. Place students in a desired grouping. This activity could be done individually or in small groups.
7. Have students cut the object cards apart on the Object Speed Cart Sort handout.
8. Have groups sort the objects from smallest/slowest speed to largest/fastest speed.
9. Students should answer (either written or discussion) the explore reflection questions on their Reflecting: How Fast is Hypersonic? handout after completing their sort:
    - What was the order of your card sort?
    - Which cards were easiest to sort? What makes you say that?
    - Which cards were hardest to sort? What makes you say that?
10. Have groups share out or present their sort.

11. As a class, work to decide the final (correct) card sort (answers below).

Explain (20 minutes)

12. Pose the following question to your class:
    - Now that we know the ranking of the speeds of the objects, how much faster is one object compared to another?
13. Have each group (individual, small group, or class) assemble a Hypersonic Number Line. To do so, first cut along the dashed line down the middle of each sheet and cut out the grey dashed boxes around the end of the number line segments. Next, line up the number lines to form one continuous line. Finally, tape or glue the paper together. **Note: this can be time consuming. You may want to have the timelines pre-made.**
14. Discuss and define the speed of sound (343 m/s). Have students label the speed of sound on their number line. **Note that the number line is labeled in meters per second (SI units) on the bottom and miles per hour (English units) along the top. The different speeds throughout the lesson will be given in m/s. Mph is on the number line as a reference for students who may be more familiar with those units. (1 m/s = 2.237 mph)**
15. Explain what a Mach number is. Have students label their number line with the different Mach numbers. You could give each student/group a different Mach number to calculate and share out with the group. (Mach 1 = 343 m/s, Mach 2 = 2 x 343 m/s = 686 m/s, Mach 3 = 3 x 343 m/s = 1029 m/s, etc.). The number line goes up to Mach 23, you do not need to label all of them, but should go to at least Mach 5.
16. Discuss and define subsonic, supersonic, and hypersonic. Have students label their number line with subsonic (less than 343 m/s), supersonic (greater than 343 m/s), and hypersonic (greater than 1715 m/s).

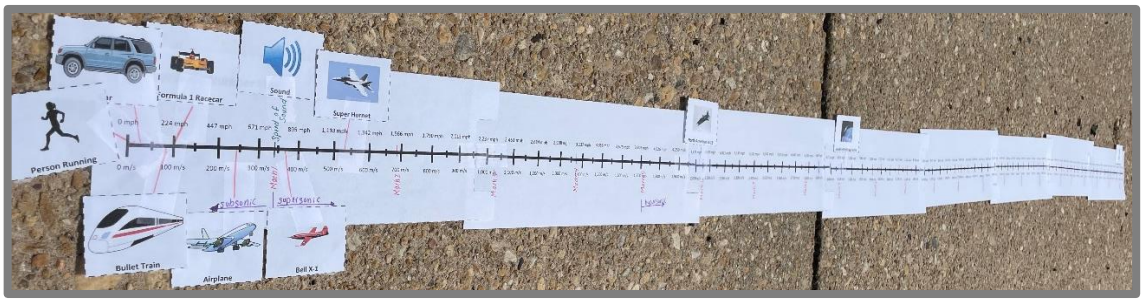


17. Have groups "plot" their objects cards on their number line based on how fast they think the objects move. Do not have students secure the cards to the number line yet.
18. After students have plotted their object cards, have them answer (either written or discussion) the explain question on their Reflecting: How Fast is Hypersonic? handout:
    - How did you decide where to put the different objects along the number line?
19. Check in on the groups thinking by either checking in with individual groups or by having groups share out to the class.

Elaborate (15 minutes)

20. Present to the students the actual average speeds of the objects. As you present the speeds, have the groups adjust their predictions along their number line. Students may secure the cards on their number line with either tape or glue. **Note: The speed of a meteor is much faster than what is on this timeline. This can lead to a discussion of how much longer the timeline would need to be to plot the meteor.**

Object	Speed in meters per second (m/s)	Speed in miles per hour (mph)
Person Running	2 m/s	4.5 mph
Car Driving	22 m/s	50 mph
Bullet Train	83 m/s	185 mph
Formula 1 Racecar	100 m/s	224 mph
Airplane	245 m/s	550 mph
Sound	343 m/s	767 mph
Bell X-1 (1st Supersonic)	364 m/s	814 mph
Super Hornet	532 m/s	1,190 mph
North American X-15 (1st Hypersonic)	2,020 m/s	4,519 mph
Satellite Orbiting	3,129 m/s	7,000 mph
Spaceship Launching	7,820 m/s	17,493 mph
Meteor	13,400 m/s	29,975 mph
Note 1 m/s = 2.237 mph		



21. Students should discuss within their groups which predictions were correct and which ones needed adjusted as they answer (either written or discussion) the elaborate questions on their Reflection: How Fast is Hypersonic? handout:
    - Which of your speed predictions were correct?
    - Which ones needed adjusted?
    - What do you notice about the placement of the objects along the number line?
    - How did your thinking about how fast objects move change?
    - What do you wonder about hypersonics?
    - How fast if hypersonic?
22. Revisit the questions from the engage part of the lesson by asking students: So now that we have learned more about the speed of different objects:
    - What is the fastest object you have seen?
    - What is the fastest way you have traveled?
    - What is the fastest object you have heard about?
    - How fast do you think those objects were going?

Evaluate (5 minutes)

23. Have individual students complete evaluate questions on the Reflecting: How Fast is Hypersonic? handout:
    - What is one thing that you are excited to share with someone else about hypersonics?
    - What is one thing that surprised you about the hypersonics lesson today?
    - What is one question that you still have about hypersonics?

STEM Career Connections

- Aerospace engineering
- Military aircraft design
- Materials scientist
- Pilot
- Car racing industry

Extensions

- As an additional or different *engage*, students could calculate their max speed. Have students time one another running a designated distance. They can then calculate their speed by dividing the distance they ran by their time.
- To help students gain more perspective on Mach numbers, you could have them convert all the speeds given in the *elaborate* part of the lesson to Mach numbers. For example: Airplane = (245 m/s) / (343 m/s) = Mach 0.71
- To help students gain more perspective the magnitude of the speeds, during the *elaborate* part of the lesson, students could use the speed equation (speed = distance / time) to calculate how long (time = distance / speed) it would take the different objects to travel the same distance. You could choose a location that is familiar to the students for the objects to travel. For example, from the school to the nearest amusement park.
- An alternative *evaluation* could ask students to pick another object to investigate. They should: (a) find how fast the object moves in m/s and mph, (b) calculate the speed in terms of Mach number, (c) classify the object as subsonic, supersonic, or hypersonic and (d) add it to their number line.

References & Resources

National Air and Space Museum. (n.d.). *Bell X-1 Glamorous Glennis*. https://airandspace.si.edu/collection-objects/bell-x-1/nasm_A19510007000

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Talented Tuber. (2017, April 11). *Difference between subsonic, supersonic and hypersonic speed* [Video]. YouTube. https://www.youtube.com/watch?v=LBJ3tXCjzN0

The Daily Aviation. (2019, March 17). *This plane was designed like a giant bullet to break sound barrier: X-1 Bell history* [Video]. YouTube. https://youtu.be/W39TdNFdSug

UVA Engineering. (2021, September 27). *"Need for speed: A hypersonics lecture"- Need for speed video contest* [Video]. YouTube. https://www.youtube.com/watch?v=at2v5LJ0SUU

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Name: _____ Date: _____

Reflecting: How Fast is Hypersonic?

Engage:

1. What is the fastest object you have seen?

2. What is the fastest way you have traveled?

3. What is the fastest object you have heard about?

4. How fast do you think those objects were going?

Explore:

1. What was the order of your card sort?

2. Which cards were easiest to sort? What makes you say that?

3. Which cards were hardest to sort? What makes you say that?

Explain:

1. How did you decide where to put the different objects along the number line?

Elaborate:

1. Which of your speed predictions were correct?

2. Which ones needed adjusted?

3. What do you notice about the placement of the objects along the number line?

4. How did your thinking about how fast objects move change?

5. What do you wonder about hypersonics?

6. How fast if hypersonic?

Evaluate:

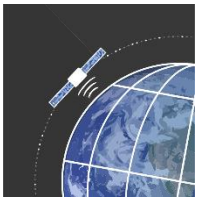
1. What is one thing that you are excited to share with someone else about hypersonics?

2. What is one thing that surprised you about the hypersonics lesson today?

3. What is one question that you still have about hypersonics?

Object Speed Cart Sort

✂ First, cut the cards out along the dotted lines. Then, sort the objects from slowest speed to fastest speed.



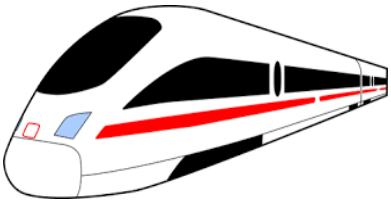
Satellite Orbiting Earth

Meteor

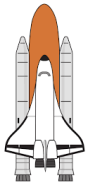
Airplane

Person Running

Super Hornet



Bullet Train

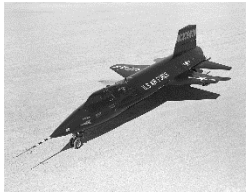


Spaceship Launching

Car

Bell X-1

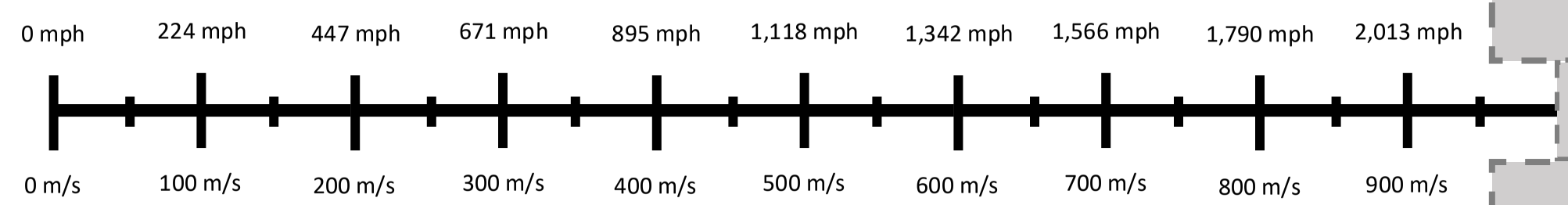
Formula 1 Racecar

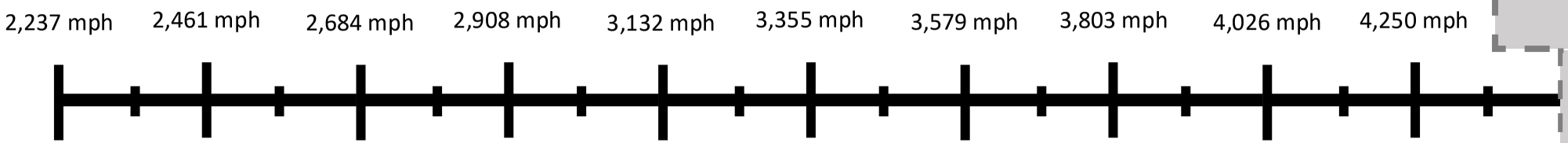


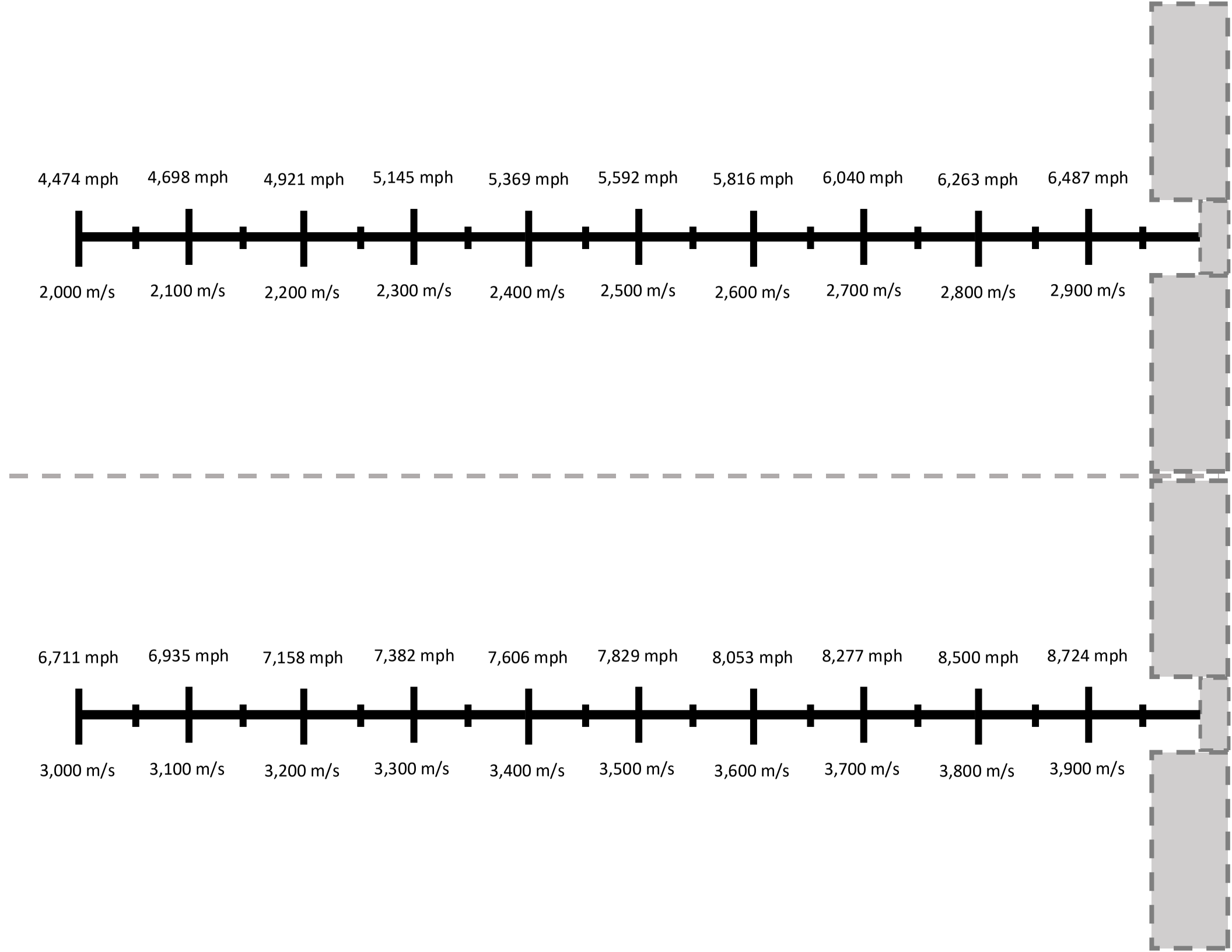
North American X-15

Sound

Hypersonic Number Line



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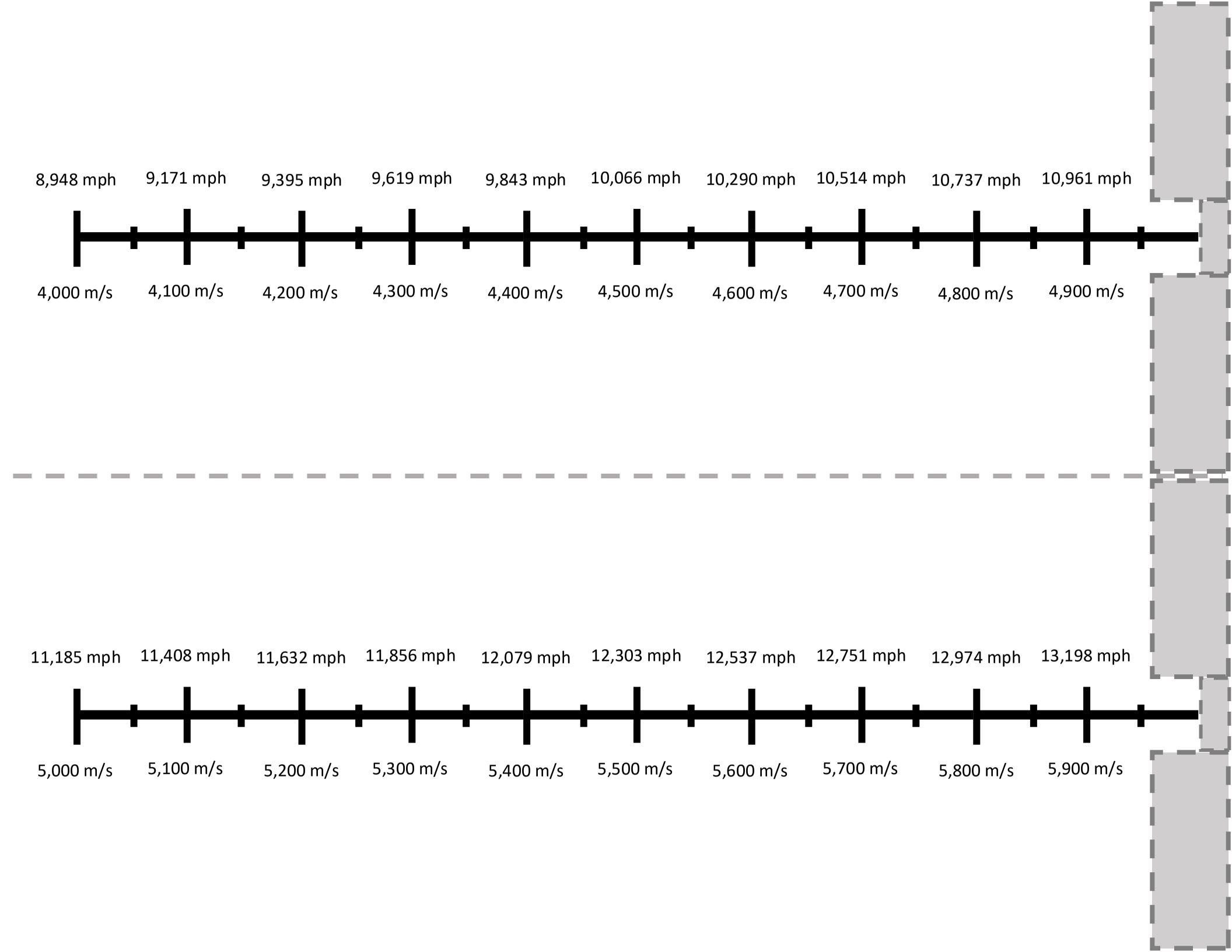
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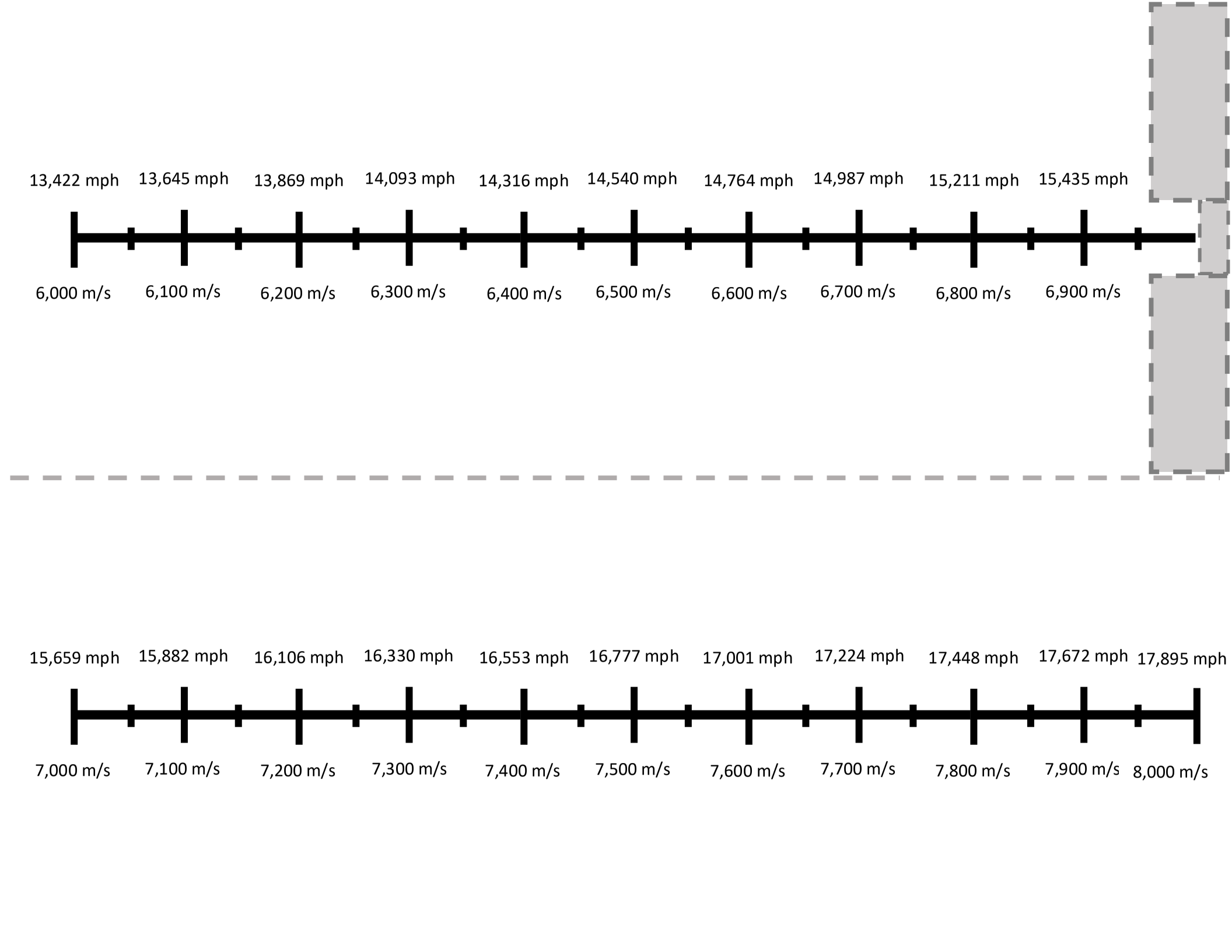
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