How to Design and Create a Commercial Aircraft Radar Receiver and Decryptor

Nicholas Pease

Outline

- **About Me**
- **Five Guiding Principles**
- **My Project**
- **Plans after High School**
- **Conclusion**
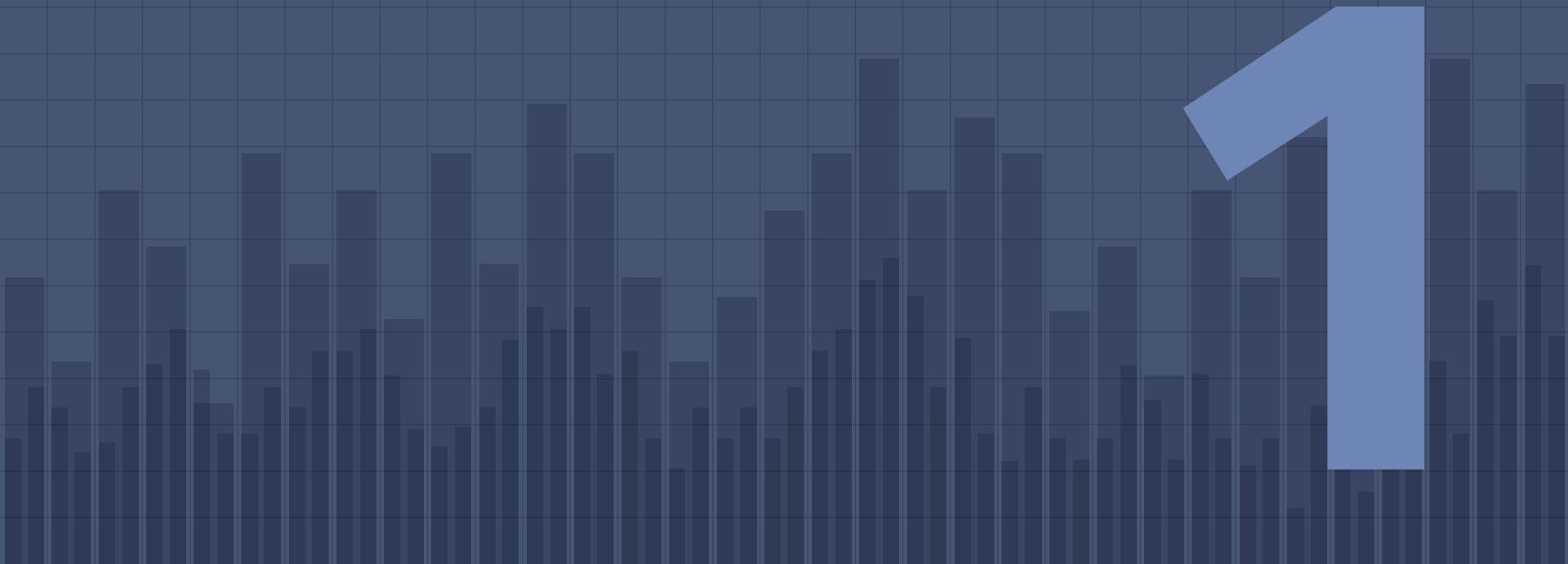
NOAA Satellite Pass – 4/18/2020

About Me

- JROTC Battalion Commander
- Treasurer of National Honor Society
- Aubuchon Hardware Sales Member
- Avid Programmer and Developer

Guiding Principles

1

Independent Learner (2.1, 2.3, 2.4)

- Employed since March 2019
- Working in hardware gave me room to learn
- Learned much about plumbing, electrical, etc
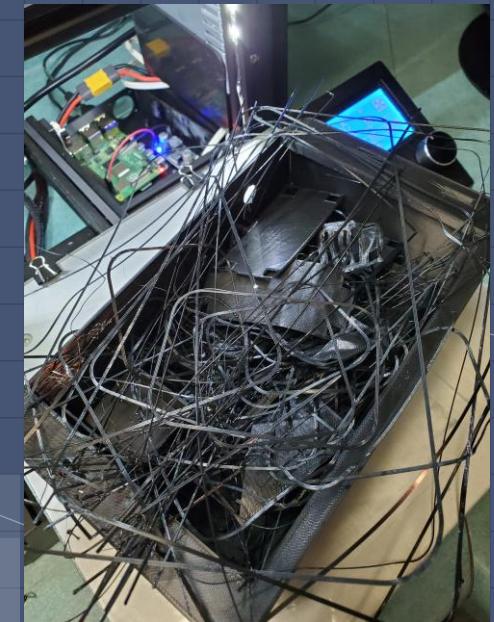
Clear and Effective Communicator (1.2, 1.4, 1.5)

- Coordinated the *Climb to Remember*
- Communicated with 10 other hiking groups
- Goal: Coordinate simultaneous hikes on all 14 mountains over 4000' in Maine

Creative and Practical Problem Solver (3.1, 3.4, 3.5, 3.6)

- Created ADS-B reception and decoding device
- No guide existed; Self developed and planned
- Had a few failures along the way

Responsible and Involved Citizen (4.3, 4.4, 4.5, 4.6)

- Worked reporting voting totals on Election Day
- Economic literacy at work
- Ran the 2019 Giving Tree Program

Integrative and Informed Thinker (5.1, 5.2, 5.3)

- Sophomore year science fair

- Analyzed over 550 lines of GPA data and 130 lines of Survey data

- Compiled data from 5 different local schools

Senior Project

2

$532.7

Total project cost

16 Months
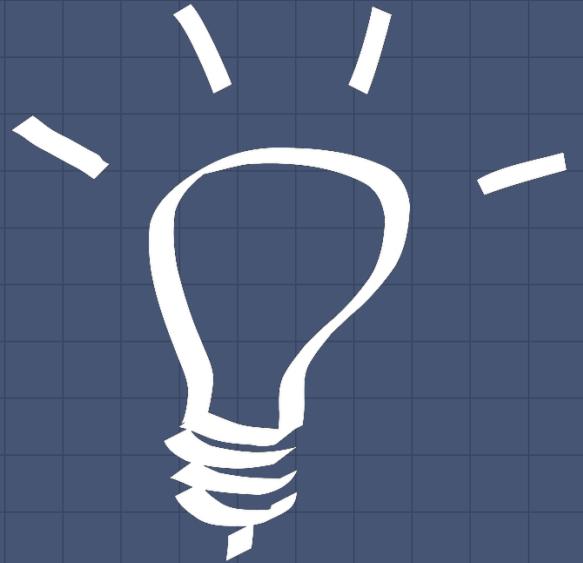
From original emails to project completion

58,224+
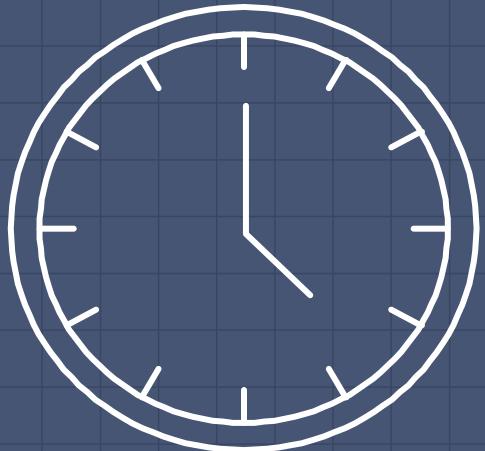
Total Lines of Code

The Idea

Design and build a completely portable, ADS-B reception and display device and develop the software to run it.
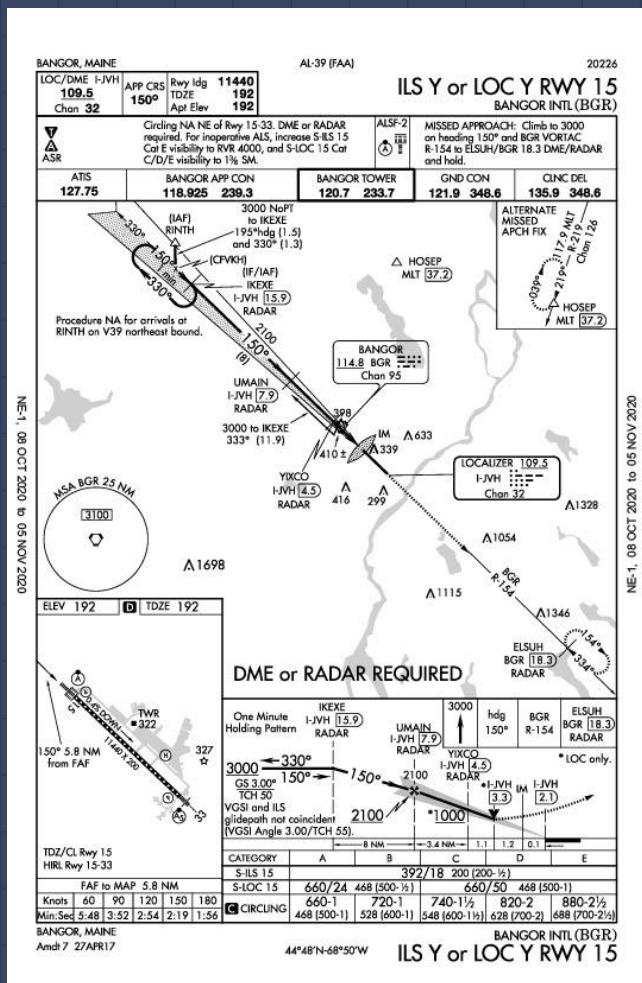
Backstory

There were 4 major components I wanted in a capstone project:
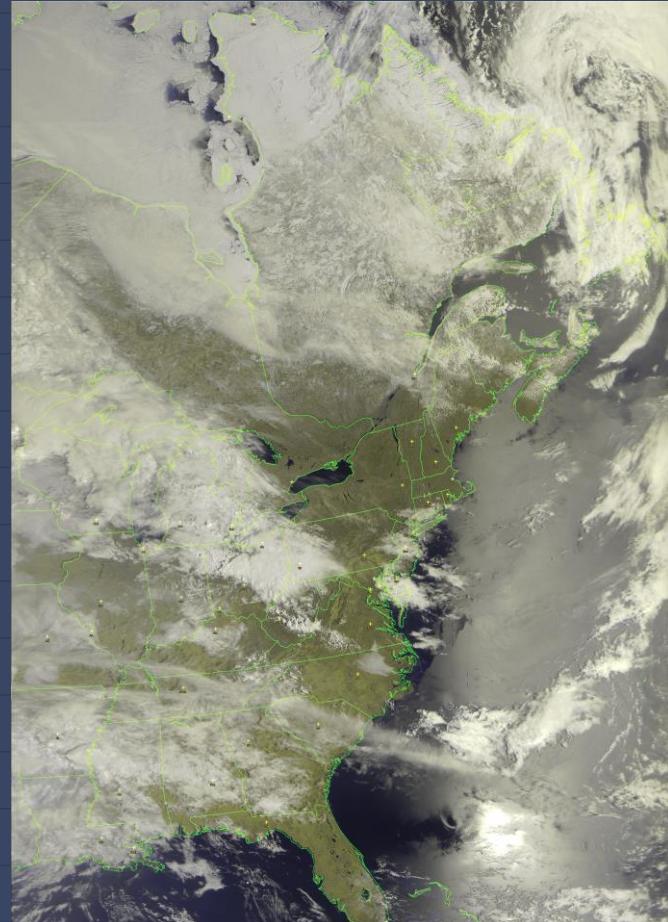
Aviation

- Love of general aviation
- On the scanner, listened to planes fly
- Tracked positions over radio
- Learned to read VFR and IFR airport charts

KBGR ILS 15 Approach

Signal Decoding

- Received APT and LRPT transmissions from weather satellites

- Designed antenna myself for orbital polarization

- Used widely available software and hardware

Russian Meteor M2-2 Satellite Image
Received 4/14/2020

Software Engineering and Development

- Began as simple webpages when I was 12

- Expanded to various Python and NodeJS bots

- Created various web applications

First Computer I Coded On
Windows 98 – Circa 1998
Running Satellite Tracking Software

3

Hardware Design and Development
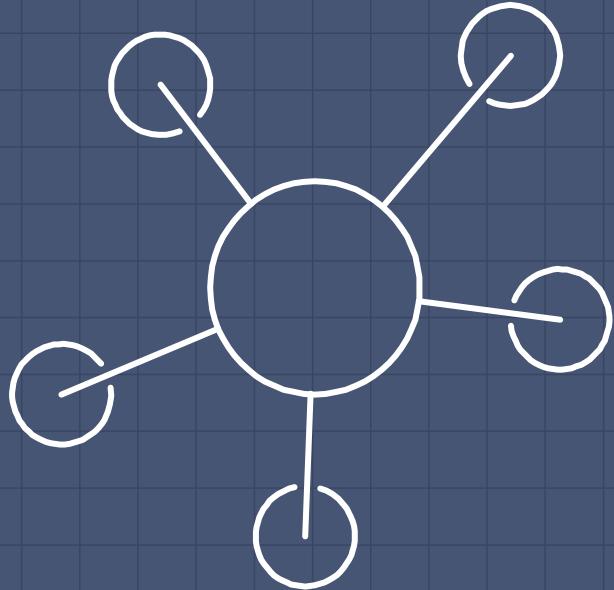
- Became interested in later years
- Modified police scanner
- Added LED's and RPI to 3D Printer

Modified Uniden Bearcat BC75XLT
Portable Police Scanner
Added Dipole and Base Station

The Science

The science of how my project works

What is ADS-B

- Automatic Dependent Surveillance – Broadcast

- FAA Replacement for Radar Stations

- Federally required since January 2020

- Provides location and position updates to ground stations and other aircraft

nBits	Bits	Abbr.	Name
5	1 - 5	DF	Downlink Format
3	6 - 8	CA	Capability (additional identifier)
24	9 - 32	ICAO	ICAO aircraft address
56	33 - 88	DATA	Data
	[33 - 37]	[TC]	Type code
24	89 - 112	PI	Parity/Interrogator ID

Type Code	Content
1 - 4	Aircraft identification
5 - 8	Surface position
9 - 18	Airborne position (w/ Baro Altitude)
19	Airborne velocities
20 - 22	Airborne position (w/ GNSS Height)
23 - 27	Reserved
28	Aircraft status
29	Target state and status information
31	Aircraft operation status

ADS-B Downlink Format and Type Codes

A D S B

AUTOMATIC: transmits information with no pilot or operator input required, twice per second.

DEPENDENT: position and velocity vector are derived from the Global Positioning System (GPS)

SURVEILLANCE: a method of determining position of the aircraft, in real-time.

BROADCAST: transmitted information available to anyone with the appropriate receiving equipment.
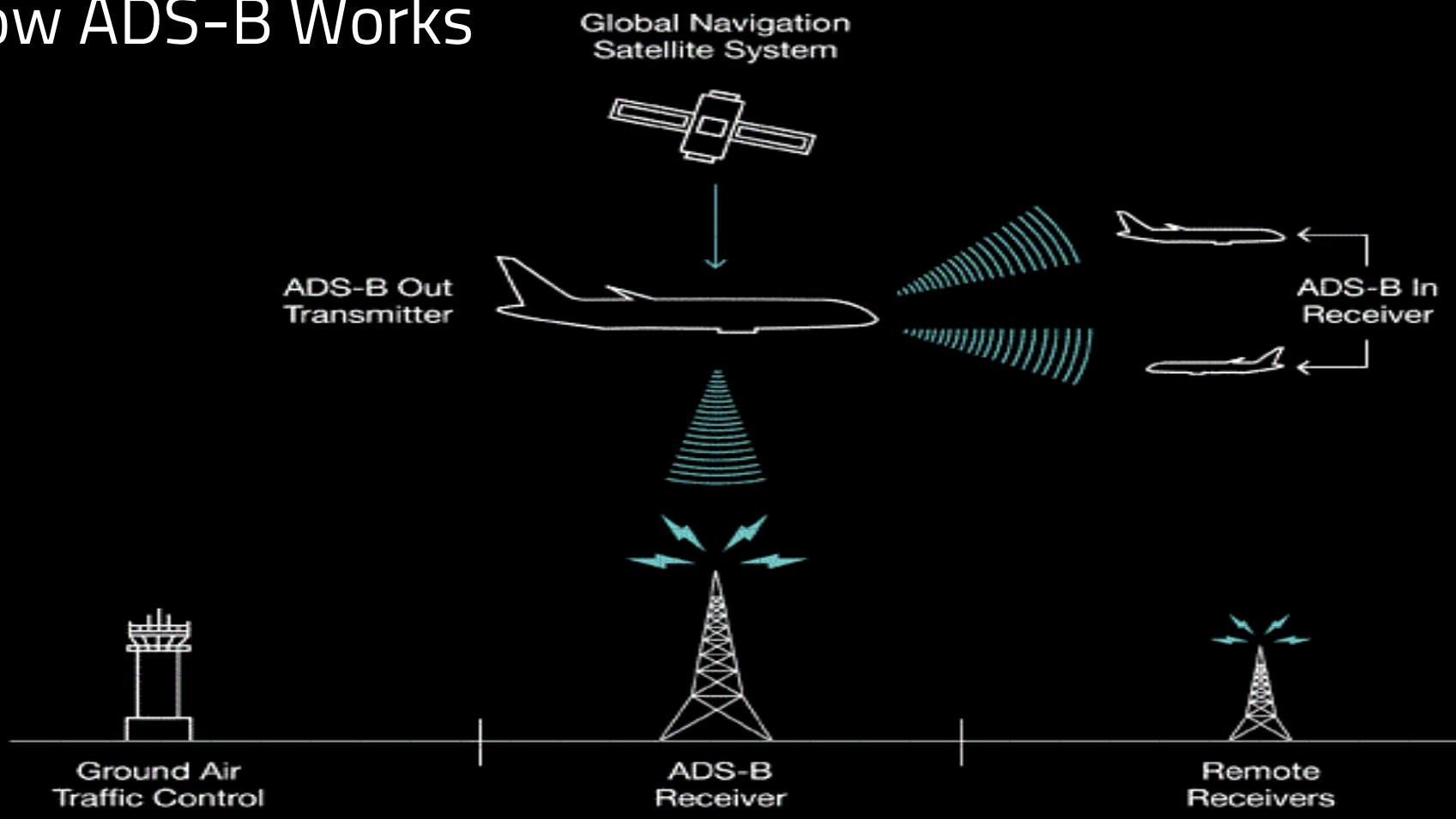
What does ADS-B Do?
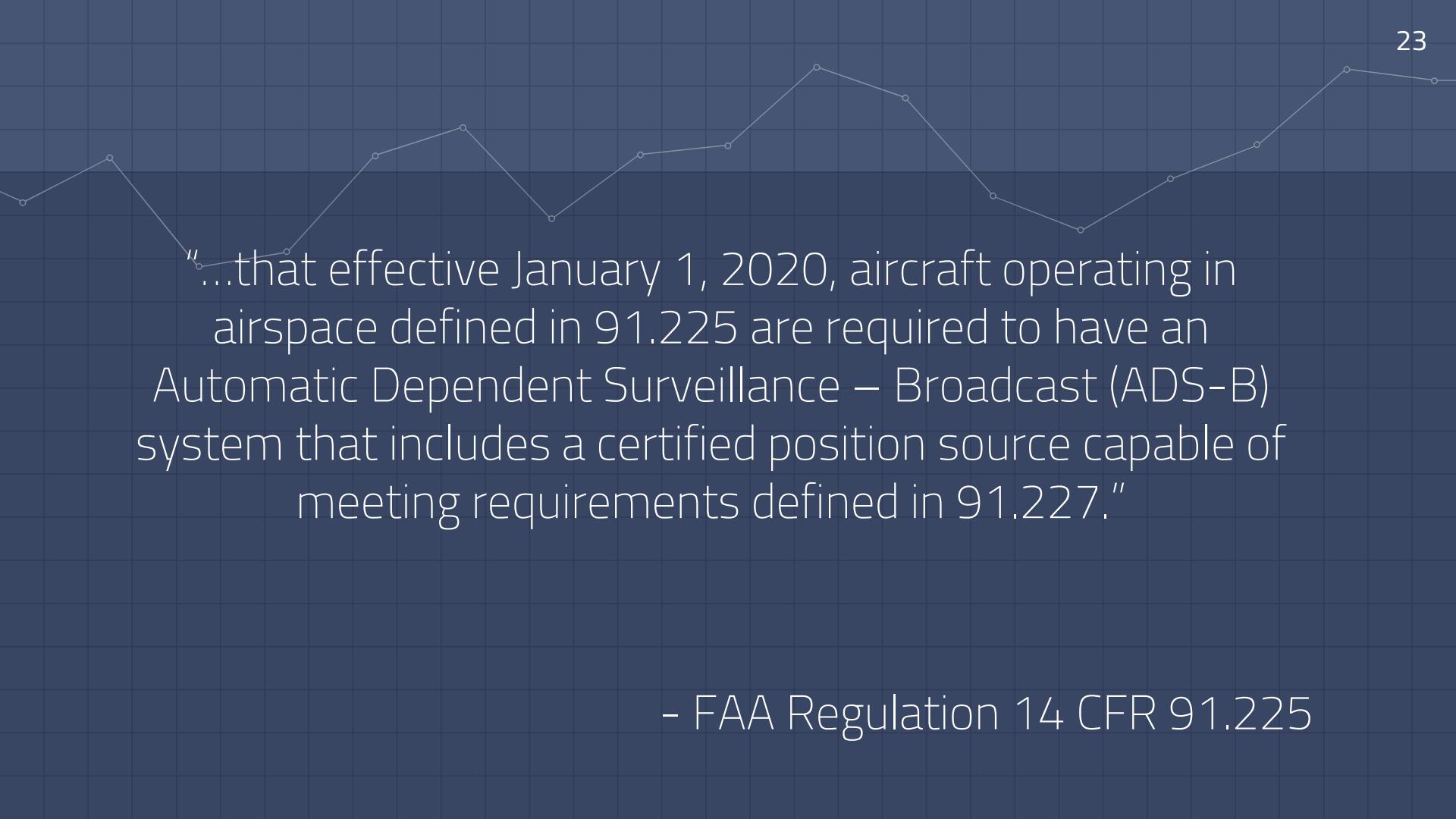
- Replacement for conventional radar systems
- Provides regional airports and ARTCC with position data
- Allows airports and air traffic control accurate timely data

Example Air Traffic Control Screen

How ADS-B Works

Global Navigation Satellite System

ADS-B Out Transmitter

ADS-B In Receiver

Ground Air Traffic Control

ADS-B Receiver

Remote Receivers

Source: Boeing AERO

"…that effective January 1, 2020, aircraft operating in airspace defined in 91.225 are required to have an Automatic Dependent Surveillance – Broadcast (ADS-B) system that includes a certified position source capable of meeting requirements defined in 91.227."

- FAA Regulation 14 CFR 91.225

How My Device Works

Step 1
Aircraft flies into radio range (200NM)

Step 2
Device logs aircrafts ICAO address and waits for positional data

Step 3
Aircraft transmits periodic surface position
OR
ARTCC "interrogates" airplane for position

Step 4
Device logs current GPA coordinates, speed, and heading and displays on map

Step 5
Aircraft continues transmitting more frequent heading and speed updates. Device logs these and updates position of aircraft

The Project

With those 4 components in mind,

And the science feasible,

I had a vision for what I wanted to do

Planning and Process

STEP 1	STEP 2	STEP 3
Planning, Research, Initial Sketches, Initial Parts Order, Software Design	3D Case Modeling, Assembly, Additional Parts Ordering, Final Sketch	Final Assembly, Software Tweaks and Additions

Planning and Research

- Drew quick sketches to get general flow down
- Researched current technologies and capabilities
- Identified offline maps as primary concern

Email Chain from 2018 with FlightAware

Display

PSU

Antenna

Display Driver

Raspberry Pi

SDR Dongle

Initial Sketch

Initial Parts Order

Distributor	Product	Price
Amazon	6" USB Extension Cable	$4.99
Amazon	Geekworm x728 PSU	$50.89
Amazon	Stratux ADS-B Antenna	$9.99
Pishop.US	Raspberry Pi Touchscreen	$76.90
eBay	FlightAware Pro Stick Plus	$39.99
Adafruit	Raspberry Pi 4B – 2GB	$41.48
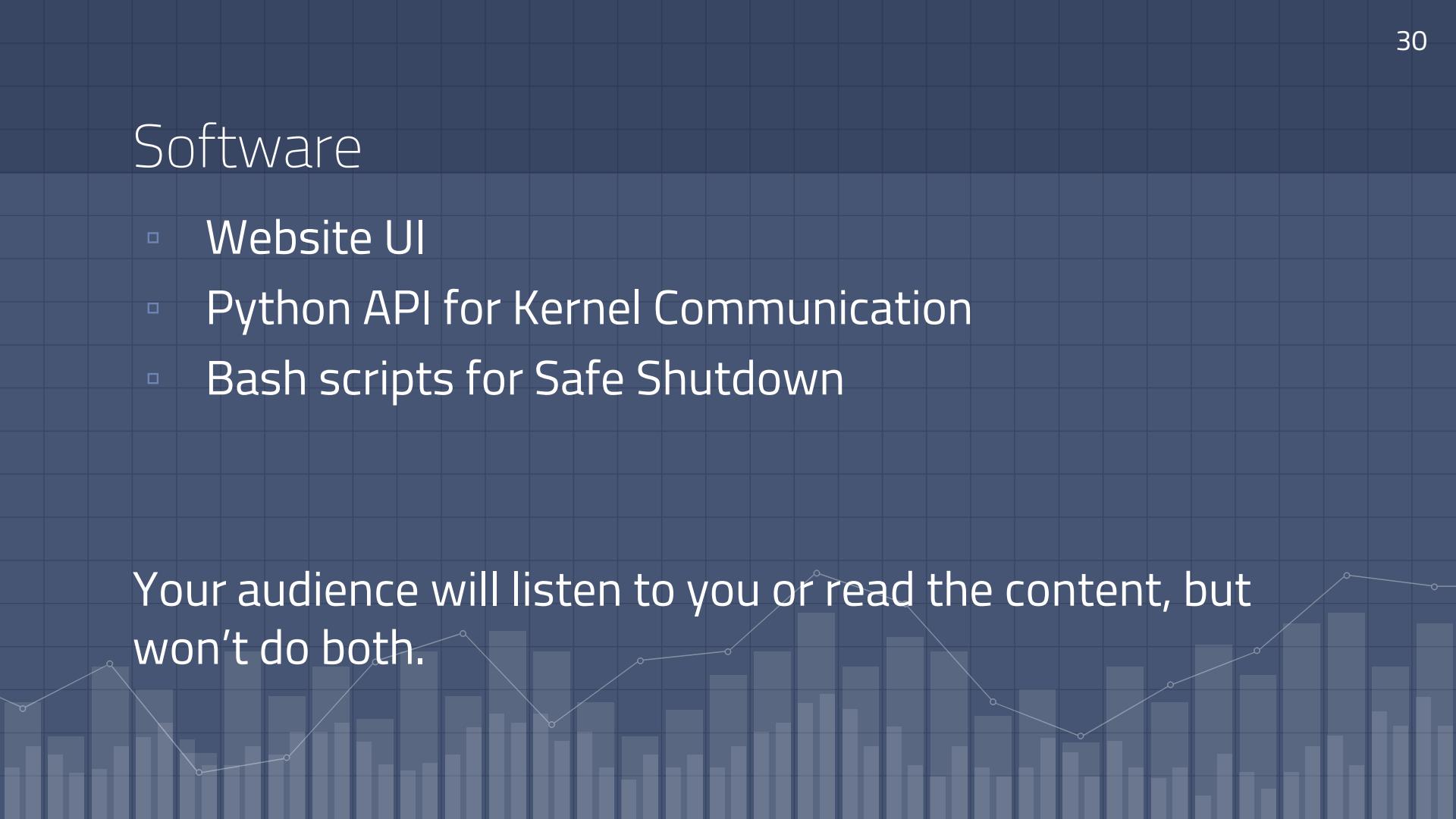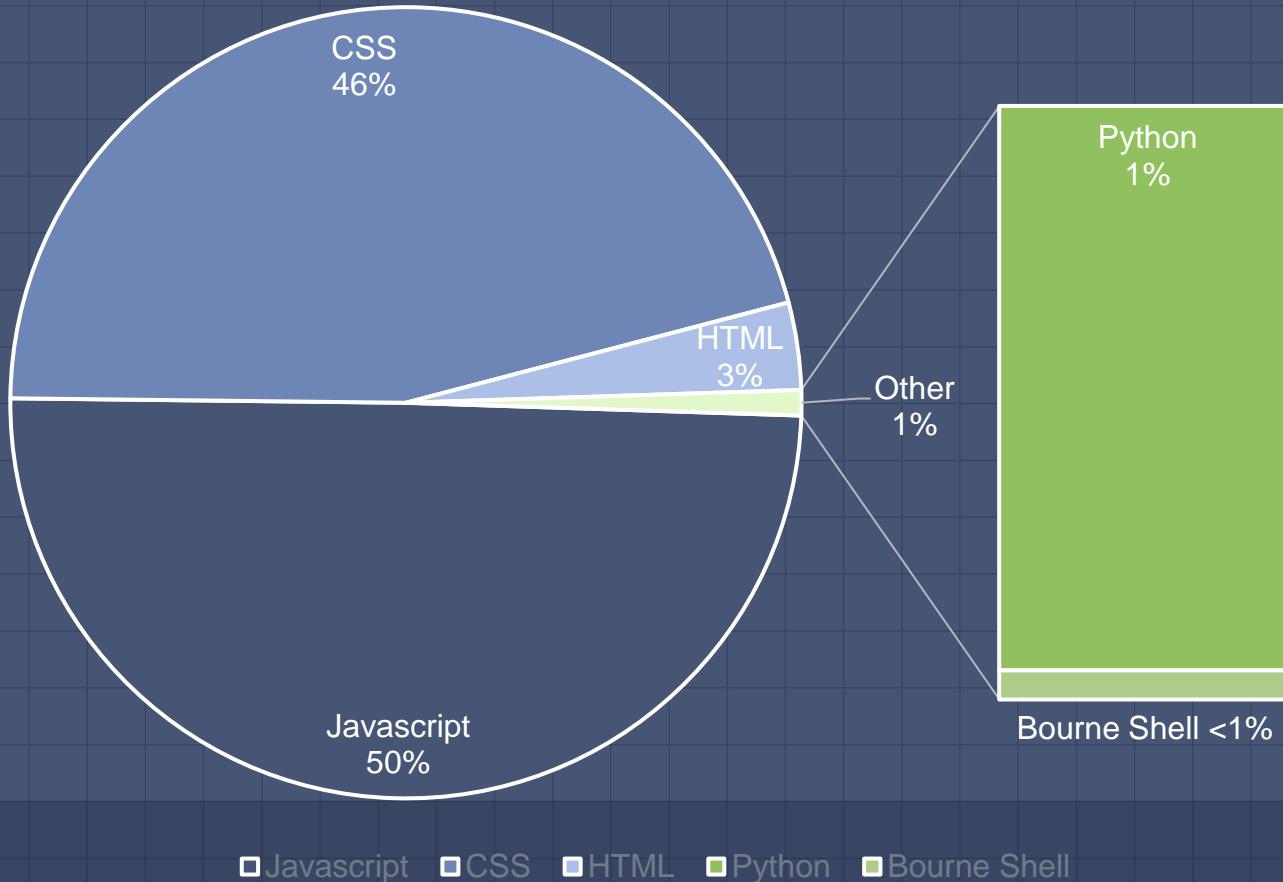
Software
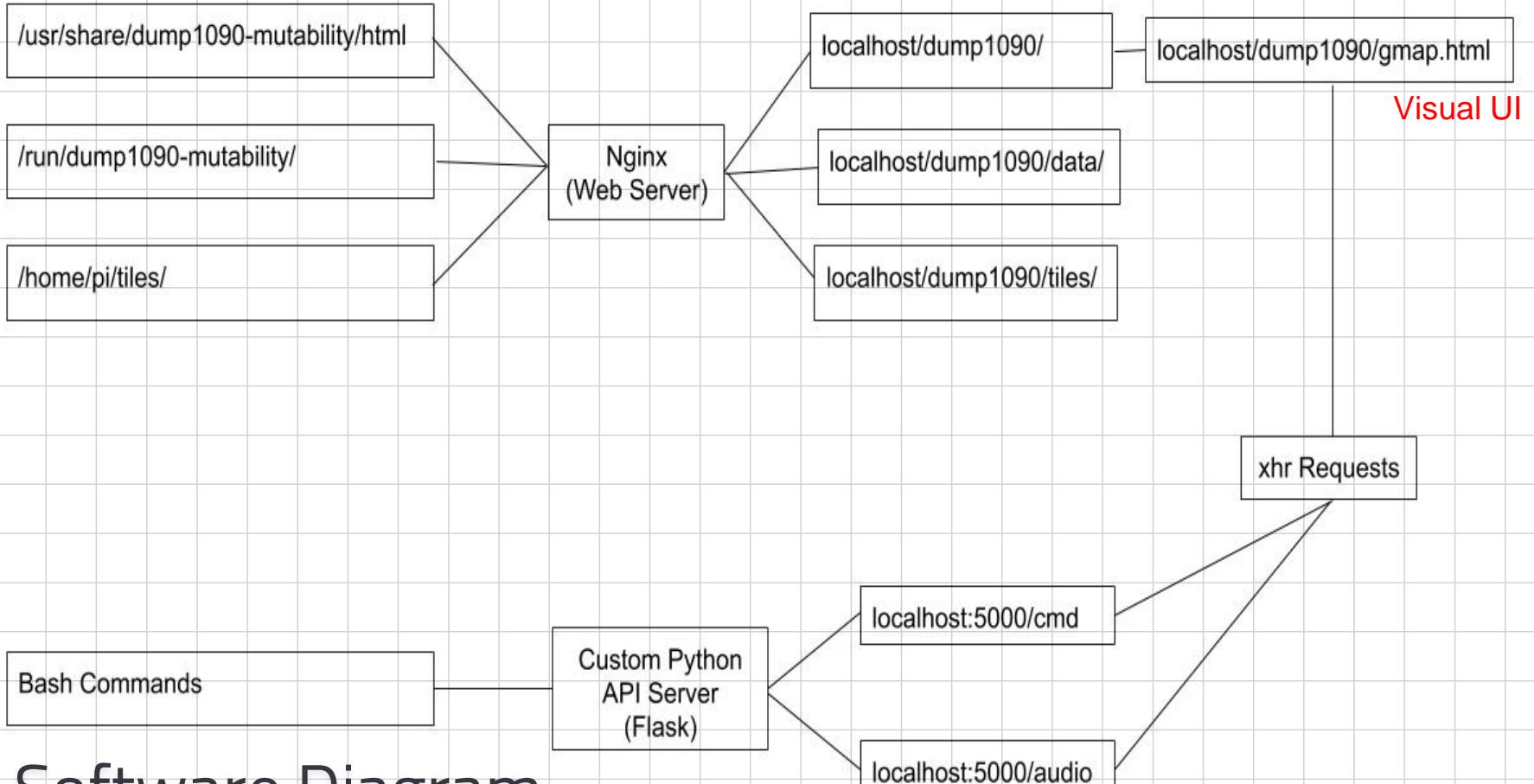
- Website UI
- Python API for Kernel Communication
- Bash scripts for Safe Shutdown

Your audience will listen to you or read the content, but won't do both.

Code Makeup By Language

CSS
46%

HTML
3%

Python
1%

Other
1%

Javascript
50%

Bourne Shell <1%

Javascript   CSS   HTML   Python   Bourne Shell

/usr/share/dump1090-mutability/html

/run/dump1090-mutability/

/home/pi/tiles/

Nginx
(Web Server)

localhost/dump1090/

localhost/dump1090/gmap.html

Visual UI

localhost/dump1090/data/

localhost/dump1090/tiles/

xhr Requests

Bash Commands

Custom Python
API Server
(Flask)

localhost:5000/cmd

localhost:5000/audio

Software Diagram

dump1090 Web Interface

- Basic Design Already Existed

- Elaborated and added METAR and LiveATC functionality

- Implemented device specific functions as well
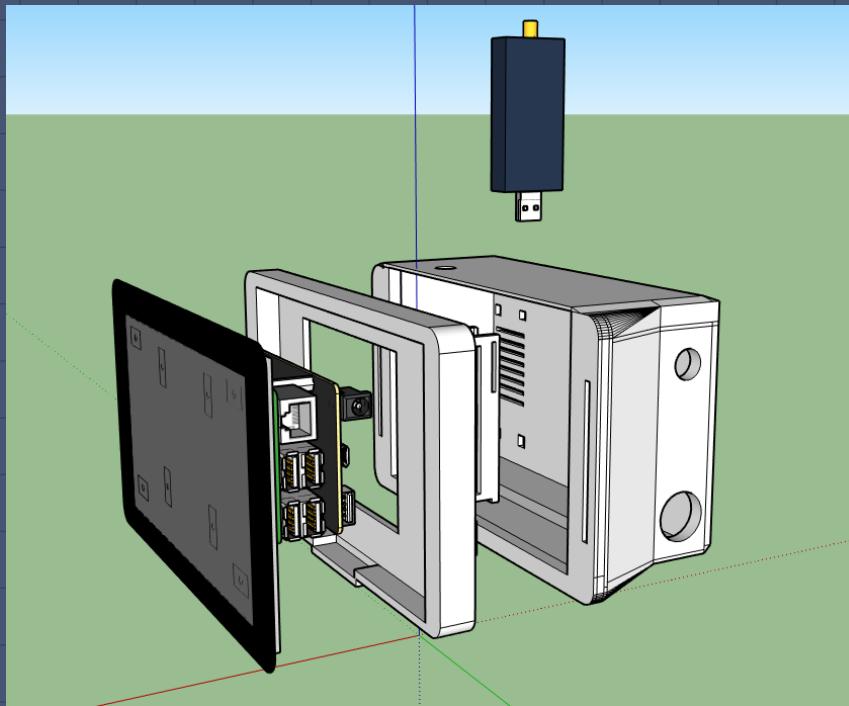
Python API Server
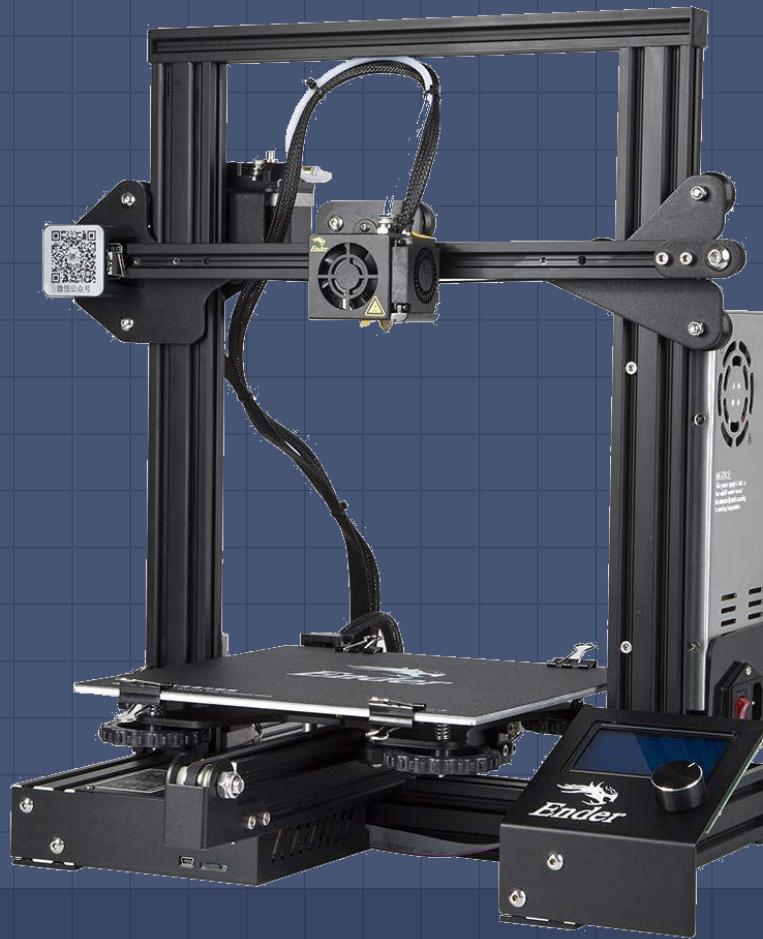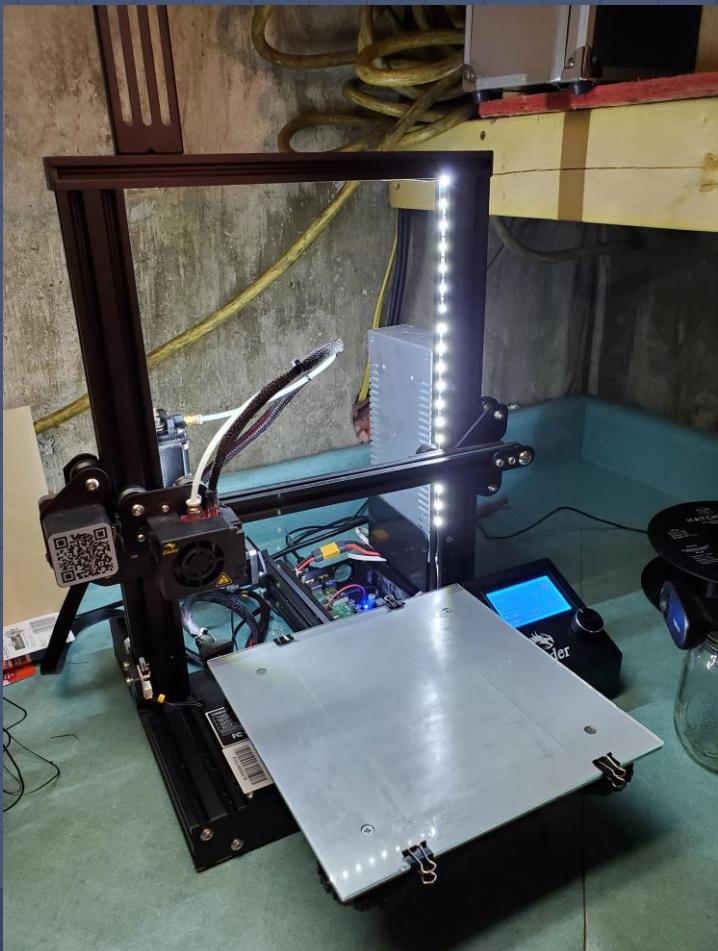
- Bridges gap from website
- Allows UI to control volume, update, change version, shutdown

LiveATC Crawler

- Input: List of Every Airport in the World

- Output: List of the audio stream URL's of every airport in the USA

- Uses LiveATC for information

3D Modeling
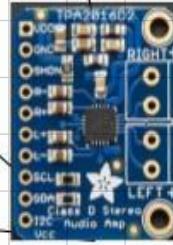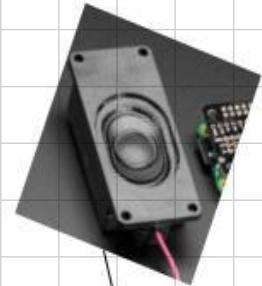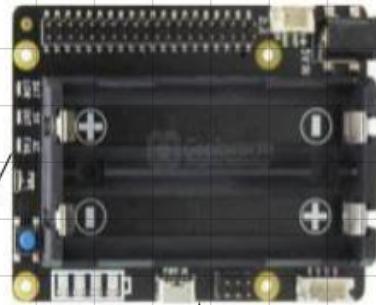
3D Printing

Additional Parts

Distributor	Product	Price
Amazon	Ender 3 3D Printer	$206.99
Amazon	Geekworm 19MM Button	$9.89
Amazon	USB Type A to 5.5x2.1 DC	$7.69
Amazon	USB 90 Degree Right Ang.	$6.99
Amazon	Cooling Fan	$7.99
Amazon	Right Angle USB Cable	$9.99
18650 Battery Shop	2 x Samsung 50E	$11.98
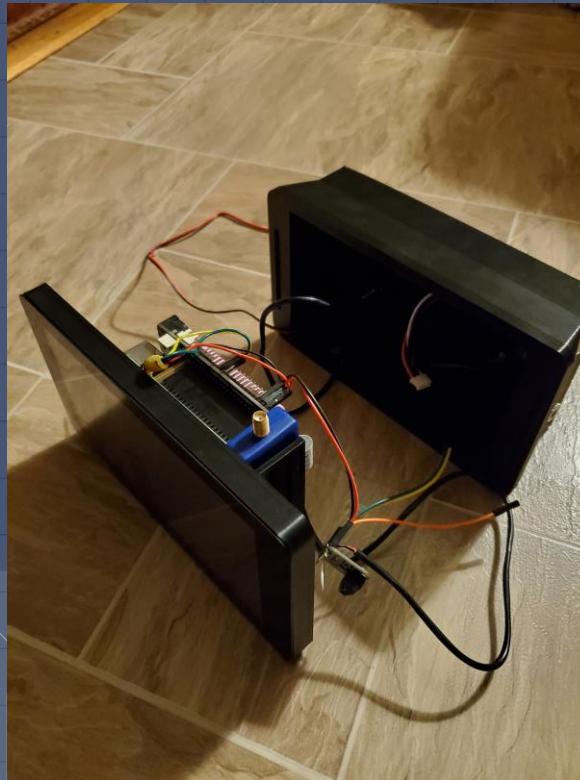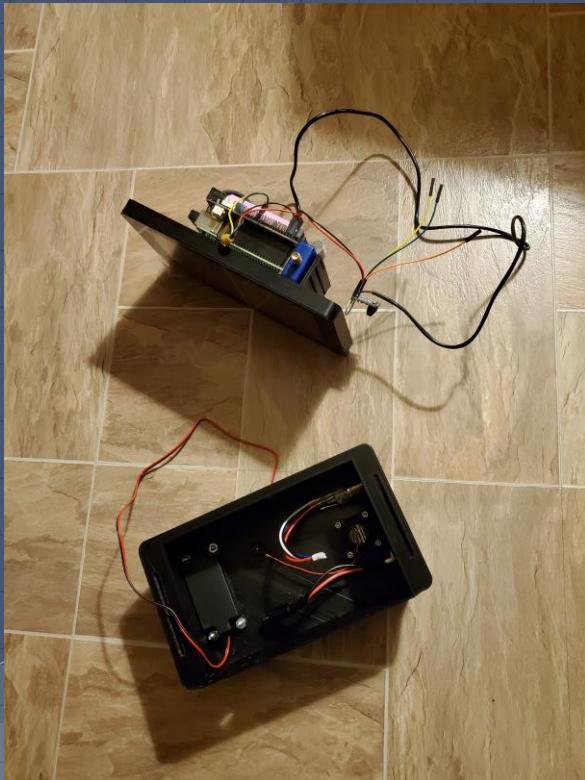
Additional Parts (Continued)

Distributor	Product	Price
Adafruit	3.5mm Stereo Plug to Pigtail Cable	$1.95
Adafruit	Stereo Enclosed Speaker	$7.50
Adafruit	TPA2016 Audio Board	$9.95
Adafruit	Jumper Wires	$4.55
Amazon	DC Panel Mount Connector	$12.99
Aubuchon	Various Nuts and Bolts	$3.99
Aubuchon	Soldering Iron	$17.99

Final Sketch

Assembly
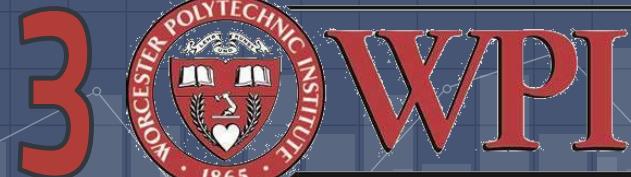
Final Result

Post Secondary Plans

3

Colleges In Contention

WENTWORTH
Institute of Technology
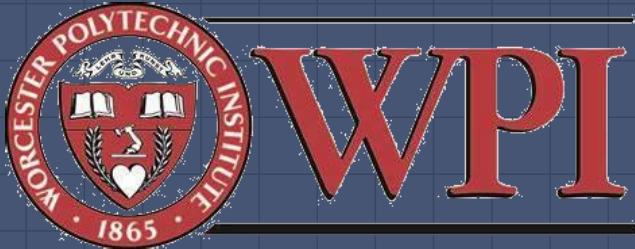
- Downtown Boston

- Great C.S. Program

- Live on Campus

- AFROTC Scholarship

- Avg Cost: $53,390 / Year

EMBRY-RIDDLE
AERONAUTICAL UNIVERSITY

- Daytona Beach, FL
- C.S, E.E, and Aeronautical Degrees
- Live on Campus
- AFROTC Scholarship and Air National Guard
- Avg Cost: $37,960 / Year

- Worcester, MA
- Technical Institute, C.S and E.E degrees.
- Live on Campus
- AFROTC Scholarship
- Avg Cost: $53,830 / Year

HOFSTRA UNIVERSITY

- Suburban New York City
- 244 Acre Campus
- AFROTC Scholarship
- Good C.S. Program
- Avg Cost: $63,748 / Year

NORWICH
UNIVERSITY®
1819

- Northfield, VT
- Senior Military College
- AFROTC Scholarship
- Good C.S, E.E and Cyber Programs
- Avg Cost: $42,950 / Year

THE UNIVERSITY OF MAINE
1865

- Downtown Orono
- Army ROTC Program
- Good C.S. and Electrical Engineering Programs
- Double Major Friendly
- Guard Payment Plans
- Avg Cost: $19,103 / Year

Scholarship Options

1. Air National Guard Tuition Waiver + G.I Bill + G.I Bill Kicker
2. Air Force ROTC Scholarship
3. Army National Guard Tuition Waiver + G.I Bill + G.I Bill Kicker
4. Pulp and Paper Scholarship
5. Maine State Science Fair Scholarship

Air National Guard Tuition Waiver + G.I Bill + G.I Bill Kicker

- UMO and Emery-Riddle Only
- Nearly 100% of College Paid For
- 6 Years of Service
- Guaranteed upon enlistment

Air Force ROTC (AFROTC) Scholarship

- Hofstra, Wentworth, Worcester, Embry-Riddle, Norwich only
- 75% -100% of College Paid For
- 4 Years on Active Duty
- Must apply for scholarship
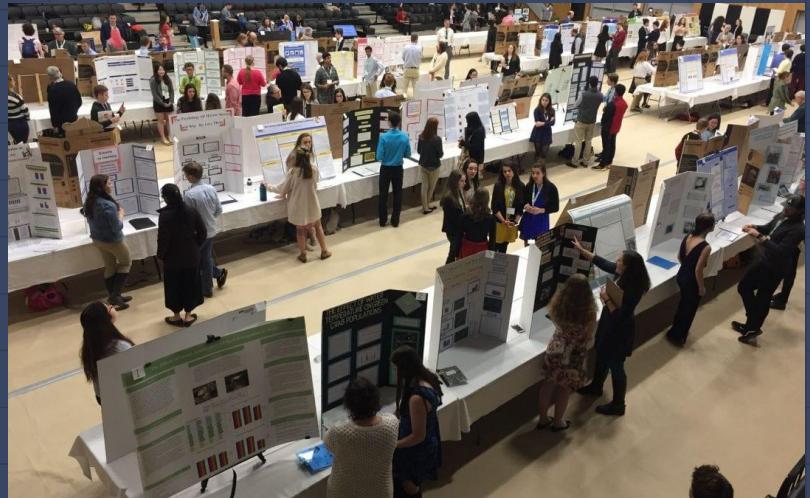
University of Maine Pulp and Paper Foundation

- UMO Only
- Full and Partial Tuition Scholarships
- Requires internships at paper mills in Maine

Maine State Science Fair Scholarship

- UMO Only
- Full Tuition, Honors College Acceptance, Research Budget
- 12 Awarded

$840,000 in scholarships
200 Students • 150 Projects • 60 Judges
12 Categories • 24 High Schools
One Day

THANKS!

Now open for questions

INSTRUCTIONS FOR USE

EDIT IN GOOGLE SLIDES

Click on the button under the presentation preview that says **"Use as Google Slides Theme"**.

You will get a copy of this document on your Google Drive and will be able to edit, add or delete slides.

You have to be signed in to your Google account.
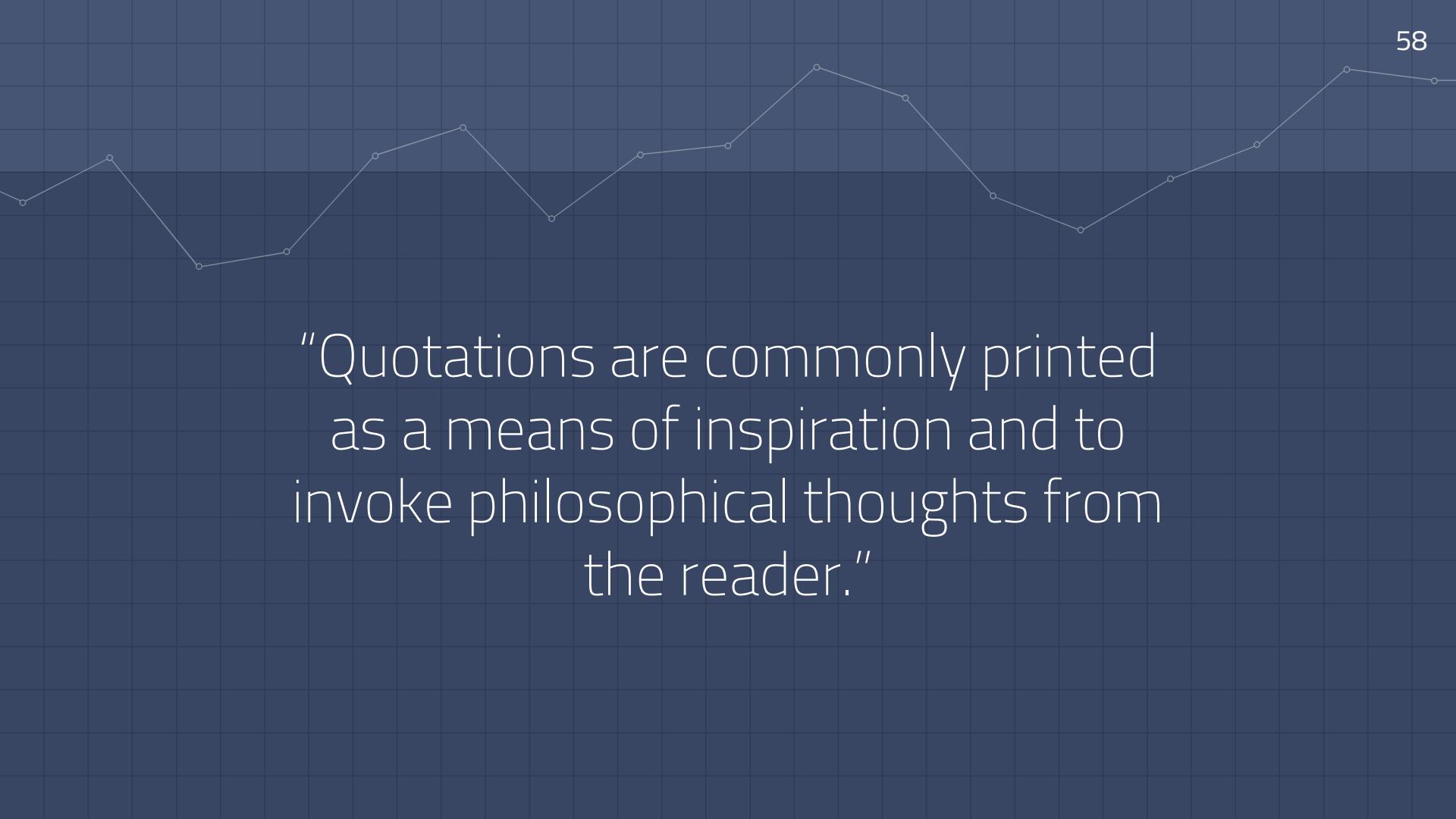
EDIT IN POWERPOINT®

Click on the button under the presentation preview that says **"Download as PowerPoint template"**. You will get a .pptx file that you can edit in PowerPoint.

Remember to download and install the fonts used in this presentation (you'll find the links to the font files needed in the Presentation design slide)

"Quotations are commonly printed as a means of inspiration and to invoke philosophical thoughts from the reader."

TRANSITION HEADLINE

Let's start with the first set of slides

1

THIS IS A SLIDE TITLE

- Here you have a list of items
- And some text
- But remember not to overload your slides with content

Your audience will listen to you or read the content, but won't do both.

BIG CONCEPT

Bring the attention of your audience over a key concept using icons or illustrations

IN TWO OR THREE COLUMNS

Yellow

Is the color of gold, butter and ripe lemons. In the spectrum of visible light, yellow is found between green and orange.

Blue

Is the colour of the clear sky and the deep sea. It is located between violet and green on the optical spectrum.

Red

Is the color of blood, and because of this it has historically been associated with sacrifice, danger and courage.

A PICTURE IS WORTH A THOUSAND WORDS
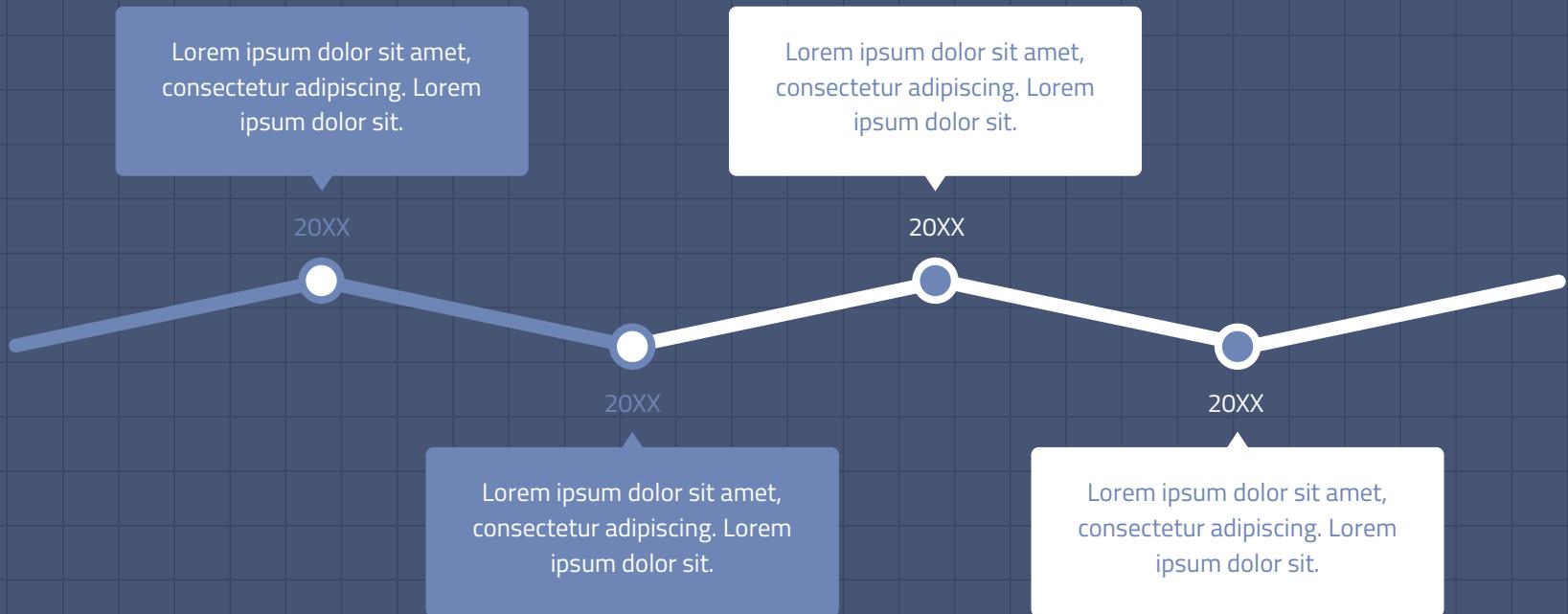
A complex idea can be conveyed with just a single still image, namely making it possible to absorb large amounts of data quickly.

WANT BIG
IMPACT?
USE BIG IMAGE.

USE DIAGRAMS TO EXPLAIN YOUR IDEAS

Lorem ipsum dolor sit amet, consectetur adipiscing. Lorem ipsum dolor sit.

Lorem ipsum dolor sit amet, consectetur adipiscing. Lorem ipsum dolor sit.

20XX

20XX

Lorem ipsum dolor sit amet, consectetur adipiscing. Lorem ipsum dolor sit.

20XX

20XX

Lorem ipsum dolor sit amet, consectetur adipiscing. Lorem ipsum dolor sit.

AND TABLES TO COMPARE DATA

	A	B	C
Yellow	10	20	7
Blue	30	15	10
Orange	5	24	16

MAPS

our office

89,526,124

Whoa! That's a big number, aren't you proud?

89,526,124$

That's a lot of money

185,244 users

And a lot of users

100%

Total success!

OUR PROCESS IS EASY

STEP 1

STEP 2

STEP 3

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis sit amet odio vel purus bibendum luctus. Morbi iaculis dapibus tristique. In hac habitasse platea dictumst. Mauris convallis quam at. Morbi iaculis dapibus tristique.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis sit amet odio vel purus bibendum luctus. Morbi iaculis dapibus tristique. In hac habitasse platea dictumst. Mauris convallis quam at. Morbi iaculis dapibus tristique.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis sit amet odio vel purus bibendum luctus. Morbi iaculis dapibus tristique. In hac habitasse platea dictumst. Mauris convallis quam at. Morbi iaculis dapibus tristique.

LET'S REVIEW SOME CONCEPTS

Yellow

Is the color of gold, butter and ripe lemons. In the spectrum of visible light, yellow is found between green and orange.

Blue

Is the colour of the clear sky and the deep sea. It is located between violet and green on the optical spectrum.

Red

Is the color of blood, and because of this it has historically been associated with sacrifice, danger and courage.

Yellow

Is the color of gold, butter and ripe lemons. In the spectrum of visible light, yellow is found between green and orange.

Blue

Is the colour of the clear sky and the deep sea. It is located between violet and green on the optical spectrum.

Red

Is the color of blood, and because of this it has historically been associated with sacrifice, danger and courage.

YOU CAN ALSO SPLIT YOUR CONTENT
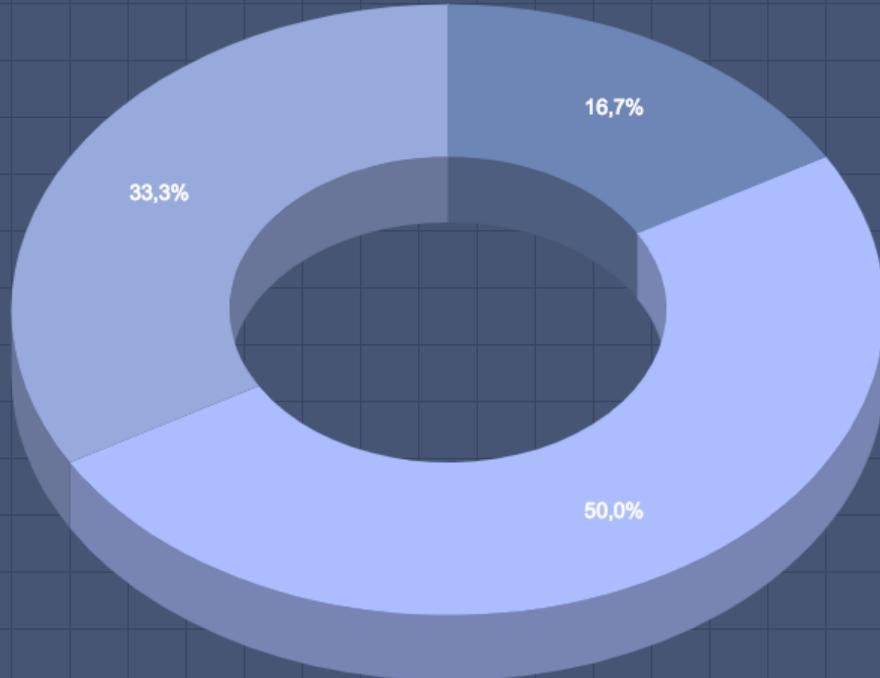
White

Is the color of milk and fresh snow, the color produced by the combination of all the colors of the visible spectrum.

Black

Is the color of ebony and of outer space. It has been the symbolic color of elegance, solemnity and authority.
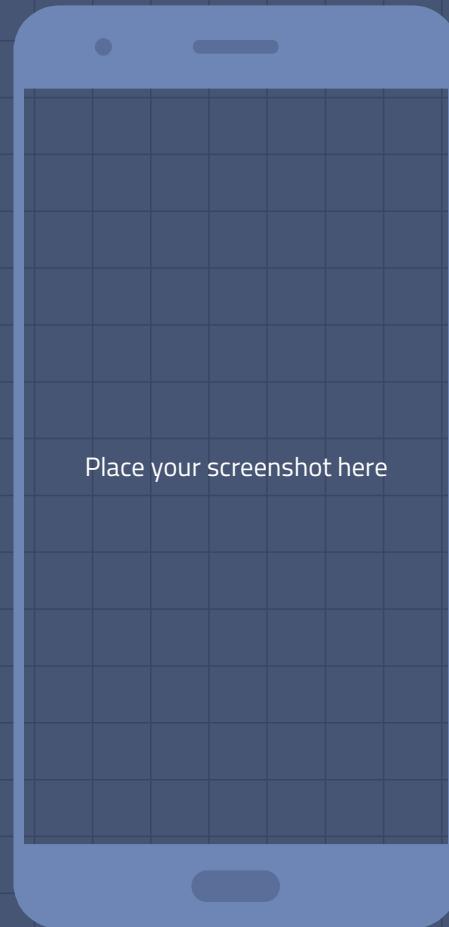
You can insert graphs from Google Sheets

MOBILE PROJECT

Show and explain your web, app or software projects using these gadget templates.

Place your screenshot here
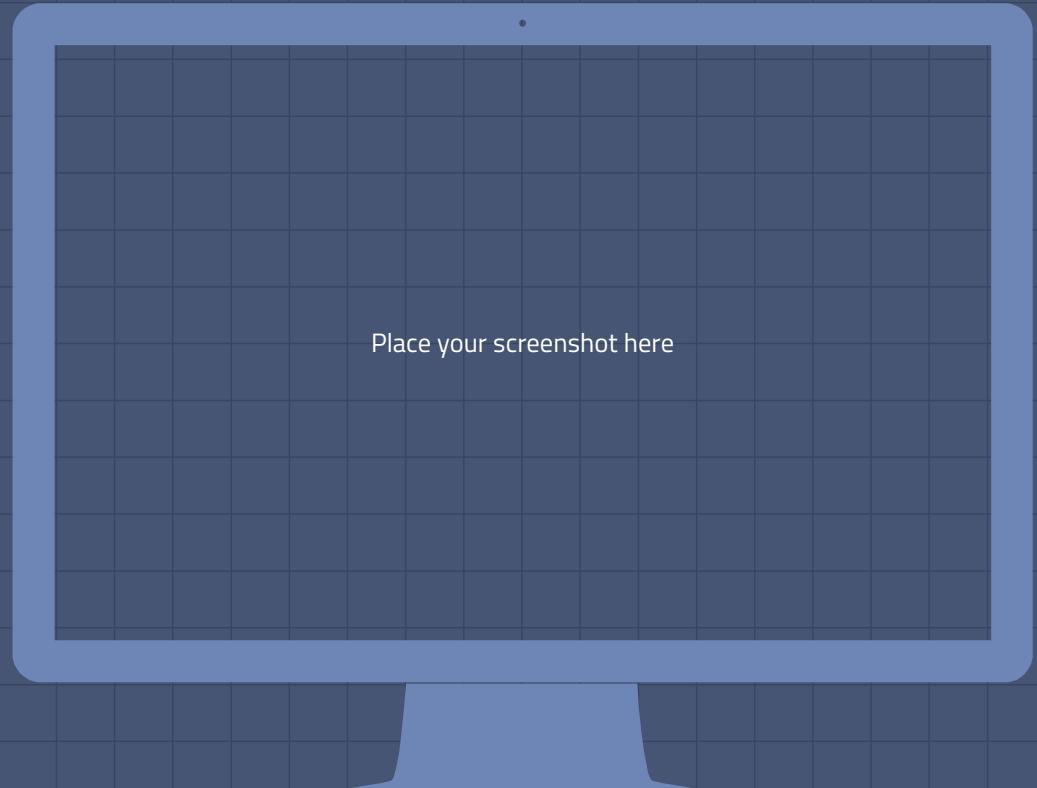
TABLET PROJECT

Show and explain your web, app or software projects using these gadget templates.

Place your screenshot here

DESKTOP PROJECT

Show and explain your web, app or software projects using these gadget templates.

Place your screenshot here

THANKS!

Any questions?

You can find me at

- @username
- user@mail.me

CREDITS

Special thanks to all the people who made and released these awesome resources for free:

- Presentation template by SlidesCarnival
- Photographs by Unsplash

PRESENTATION DESIGN

This presentation uses the following typographies and colors:

- Titles: Titillium Web ExtraLight
- Body copy: Titillium Web
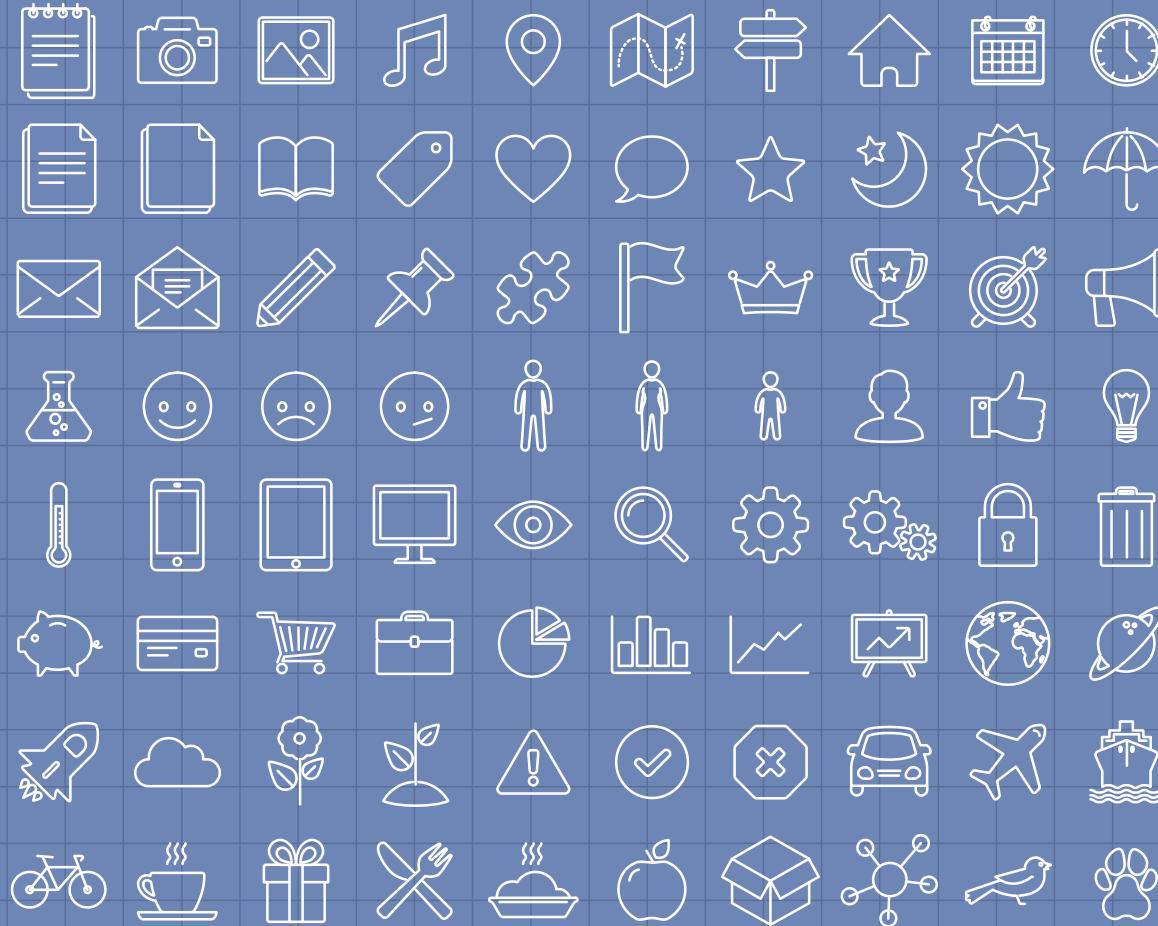
You can download the fonts on this page:

https://www.fontsquirrel.com/fonts/titillium

Bluish gray **#6e86b6** · Dark bluish gray **#465573**

You don't need to keep this slide in your presentation. It's only here to serve you as a design guide if you need to create new slides or download the fonts to edit the presentation in PowerPoint®
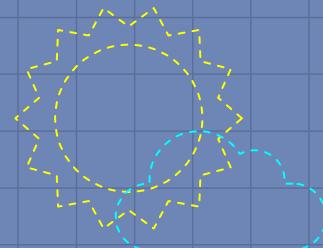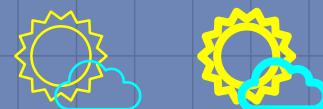
SlidesCarnival icons are editable shapes.

This means that you can:
- Resize them without losing quality.
- Change line color, width and style.
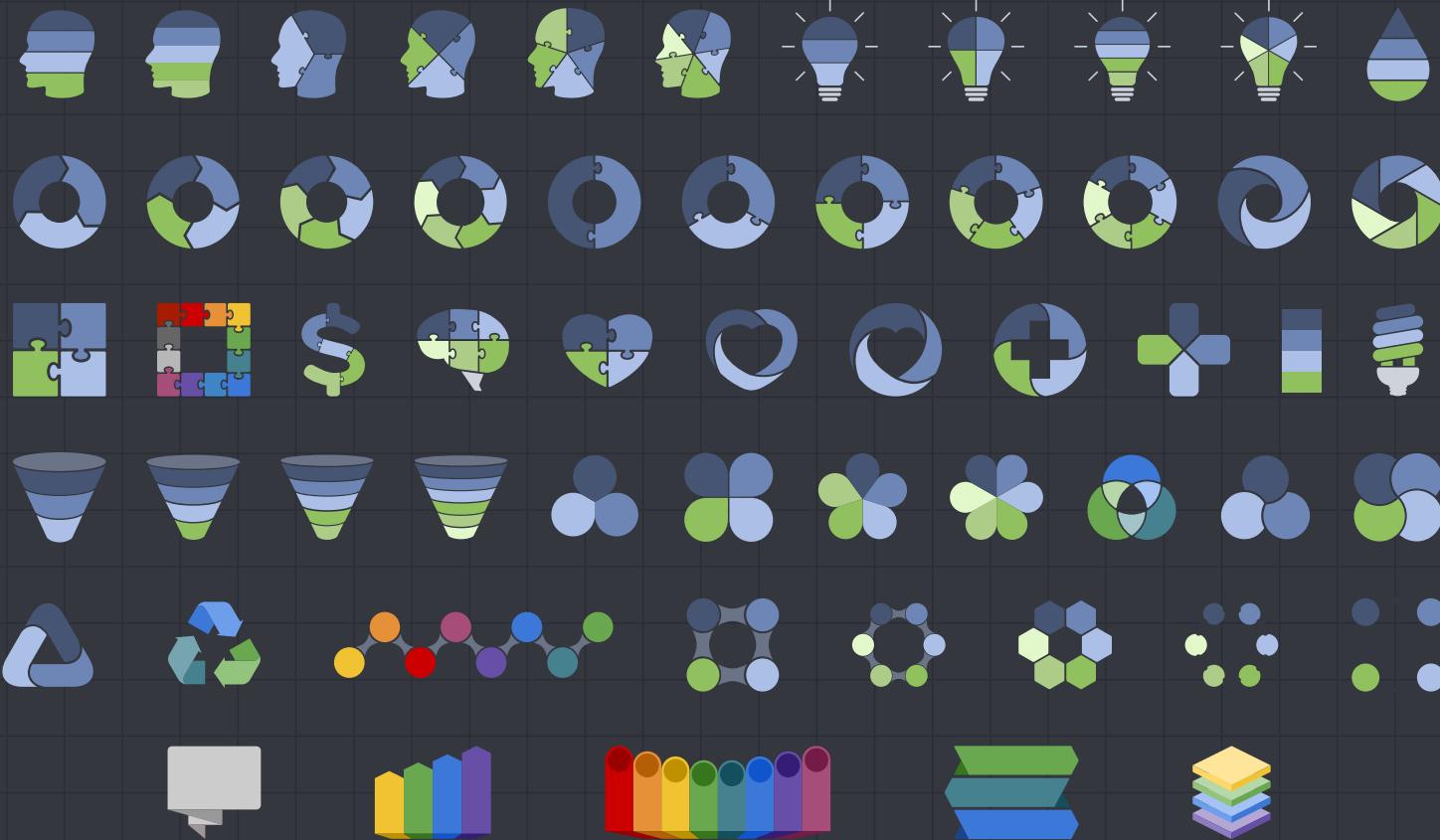
Isn't that nice? :)

Examples:

Diagrams and infographics
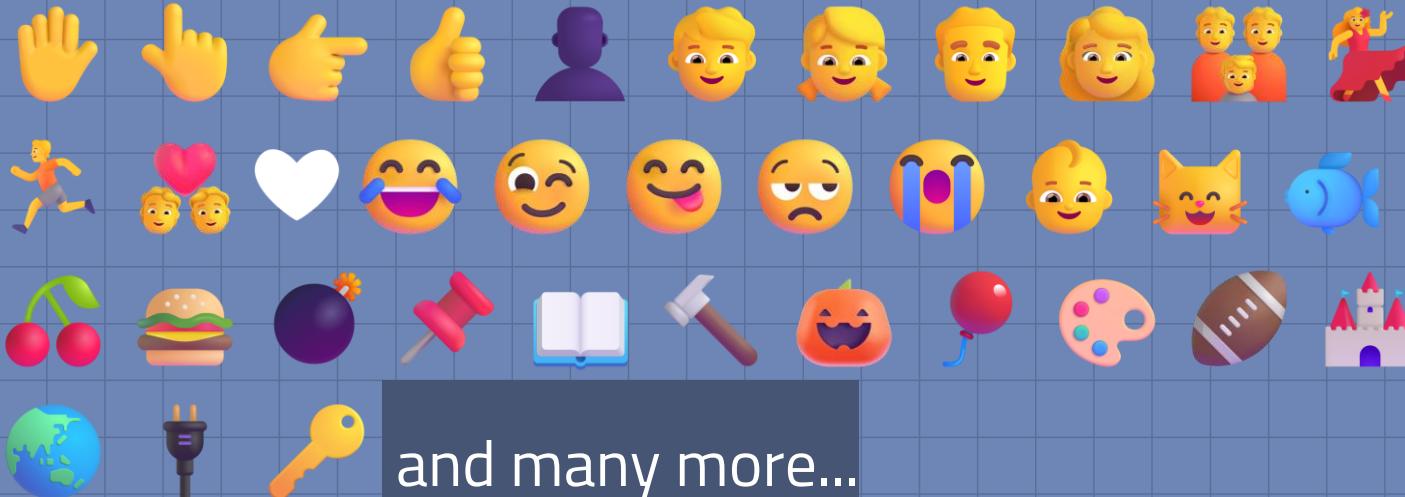
Now you can use any emoji as an icon!
And of course it resizes without losing quality and you can change the color.

How? Follow Google instructions
https://twitter.com/googledocs/status/730087240156643328

and many more...

Slides Carnival

Free templates for all your presentation needs

For PowerPoint and Google Slides

100% free for personal or commercial use

Ready to use, professional and customizable

Blow your audience away with attractive visuals