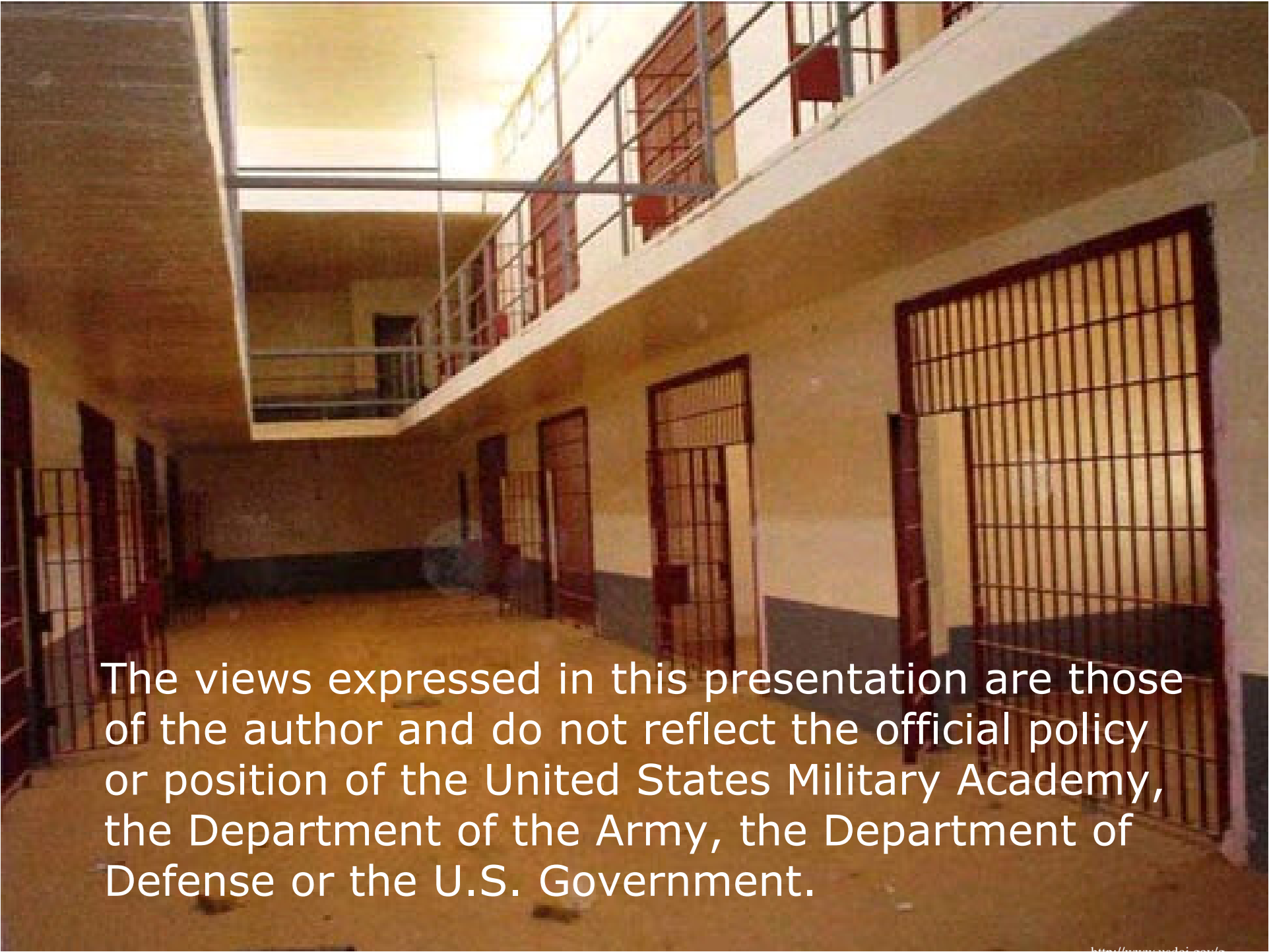


A satellite image of Earth from space, showing the eastern coast of South America and the Atlantic Ocean. The image is curved, showing the horizon of the planet. The land is green and brown, and the ocean is blue. White clouds are visible over the ocean and parts of the land.

Satellite Imagery Analysis

Greg Conti
gjconti@rumint.org



The views expressed in this presentation are those of the author and do not reflect the official policy or position of the United States Military Academy, the Department of the Army, the Department of Defense or the U.S. Government.

Outline

- Implications
- Historical Context
- Sensors
- Sensor Platforms
- Analysis
- Watching the Watcher
- More Information

Implications

Access...



Access...



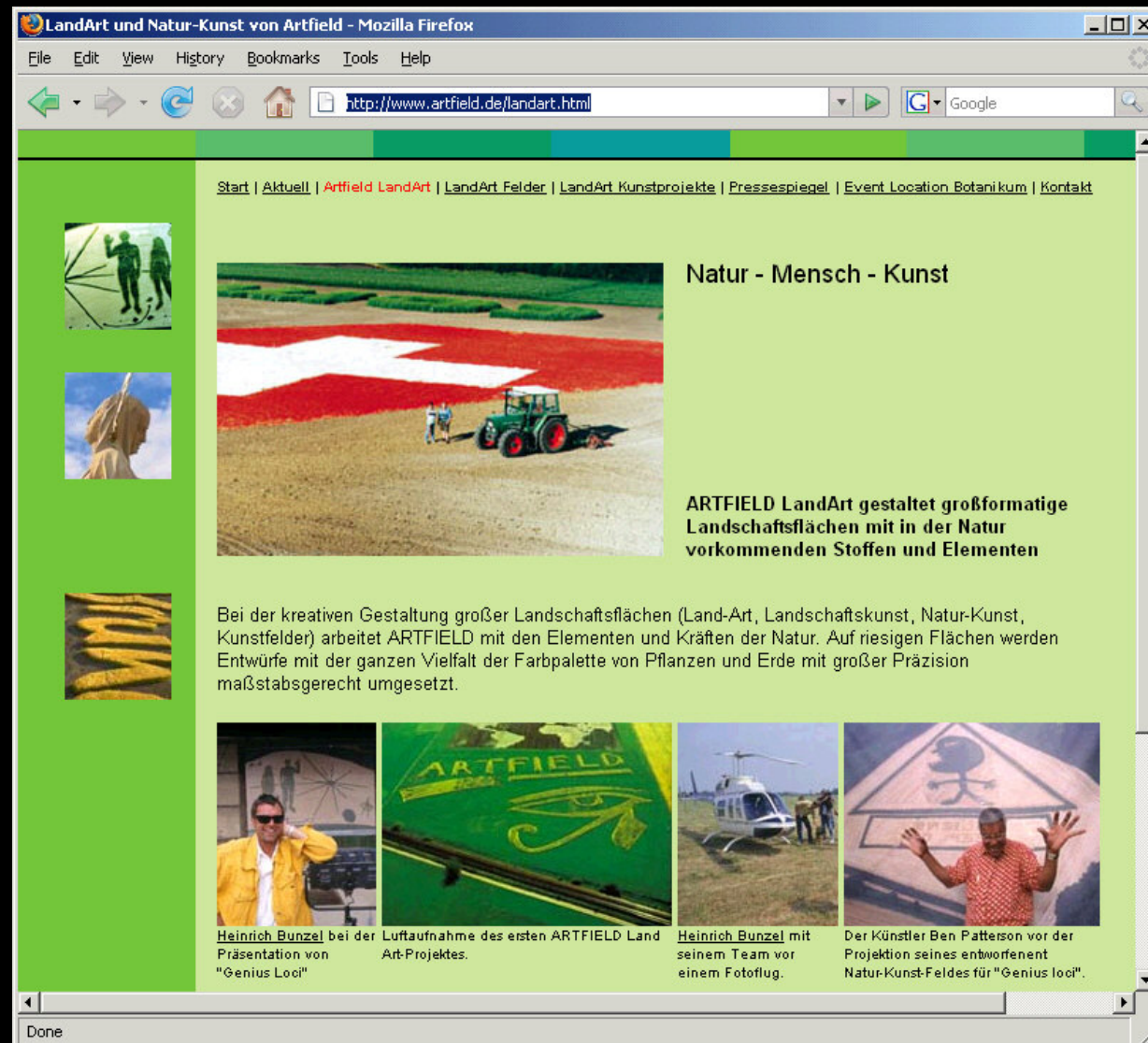
maps.google.com

Advertising



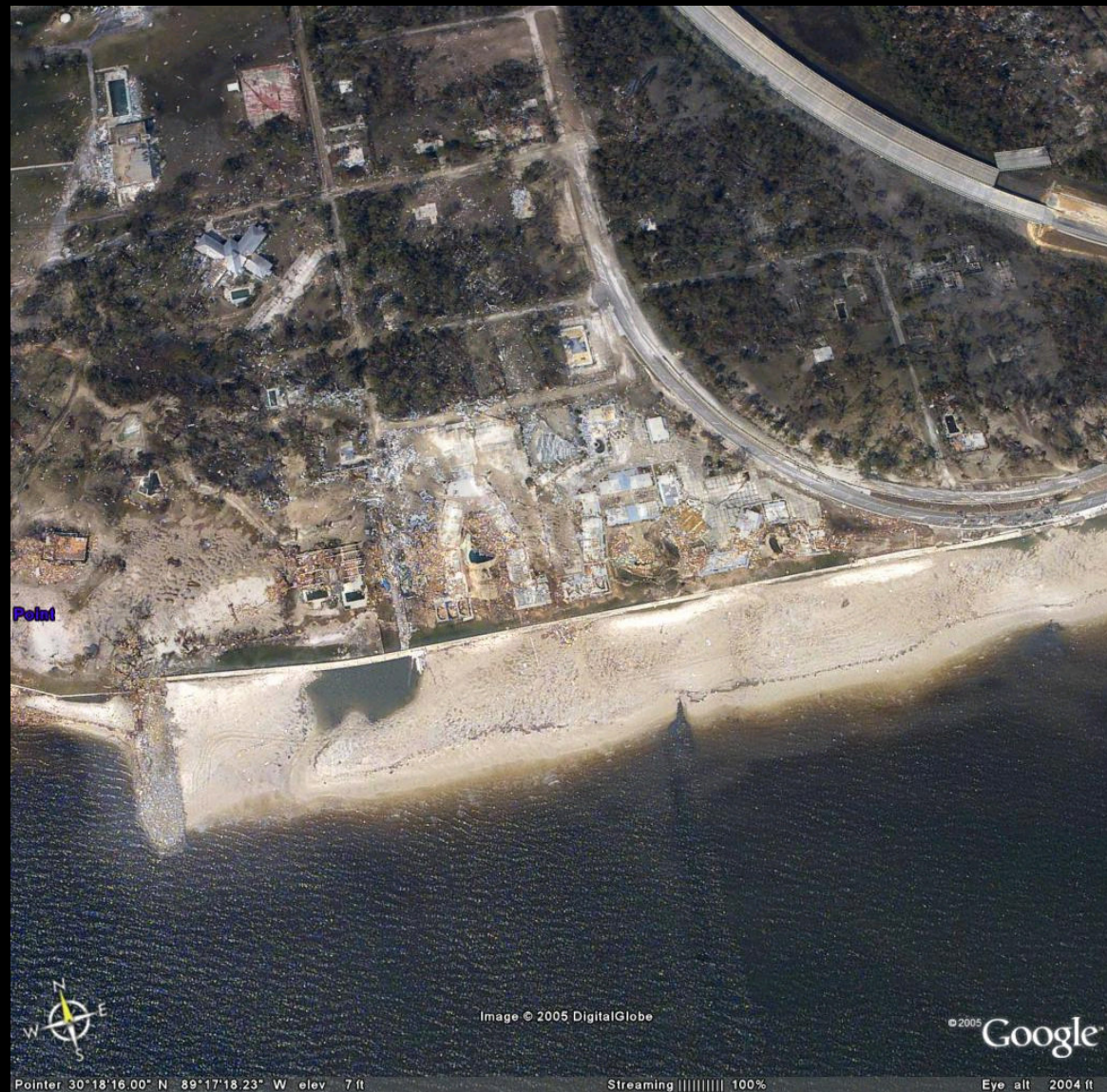
http://images.usatoday.com/life/_photos/2006/04/06/longoria-large.jpg
<http://www.gearthblog.com/images/images2006/targetroof.jpg>

Advertising Advertising



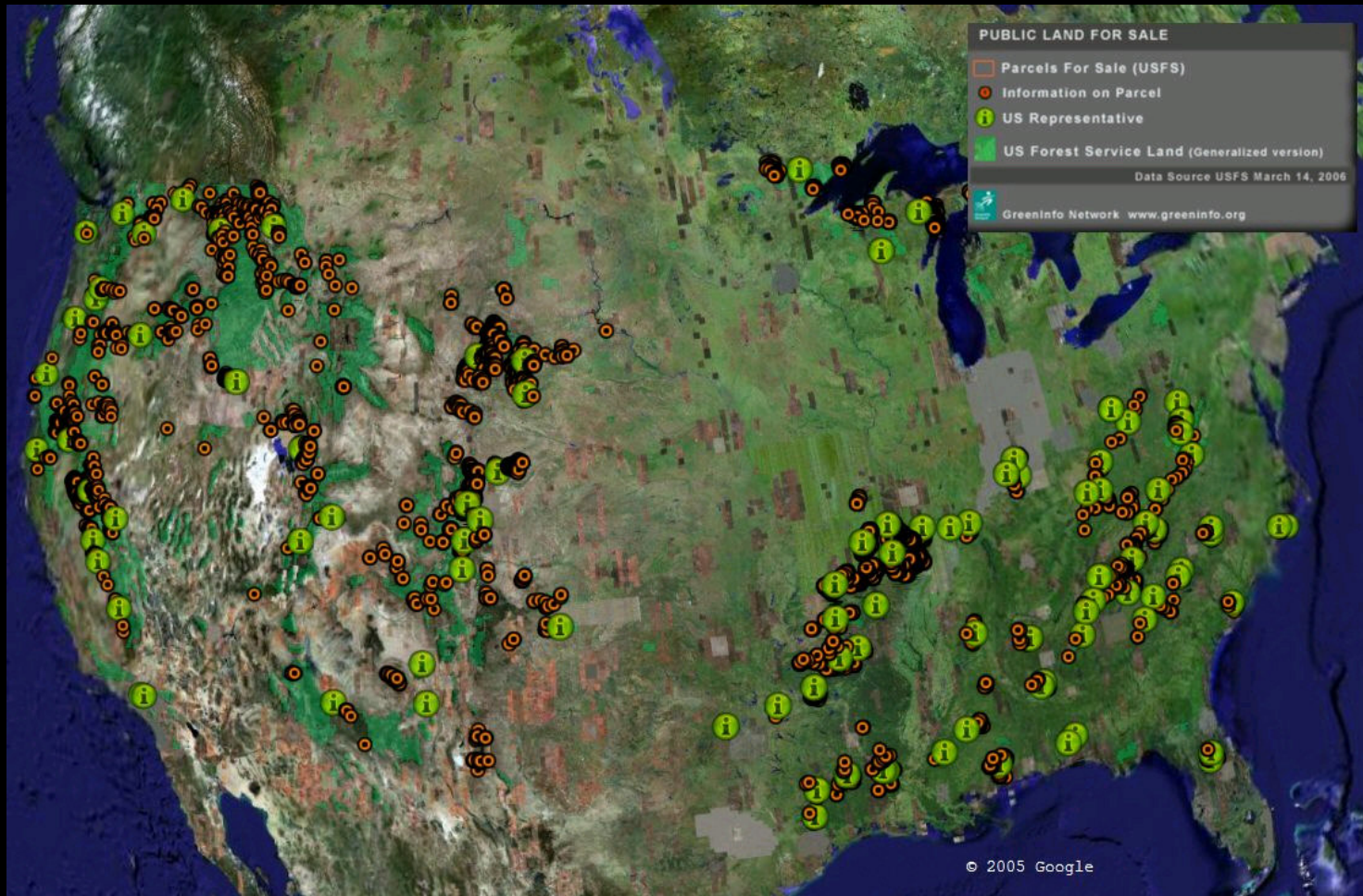
<http://www.artfield.de/>

Disaster Relief (Hurricane Katrina)



<http://earth.google.com/katrina.html>

Government Oversight (Sierra Club & Govt Land Sale)



<http://www.gearthblog.com/images/images2006/landsale.jpg>

Government Oversight (Speed Cameras in Europe)



<http://www.gearthblog.com/images/images2006/speedcams.jpg>

Getting Caught With Pants Down

Sensitive Sites: Parliament (India)



<http://cryptome.org/india/india-eyeball.htm>

Or tops off...



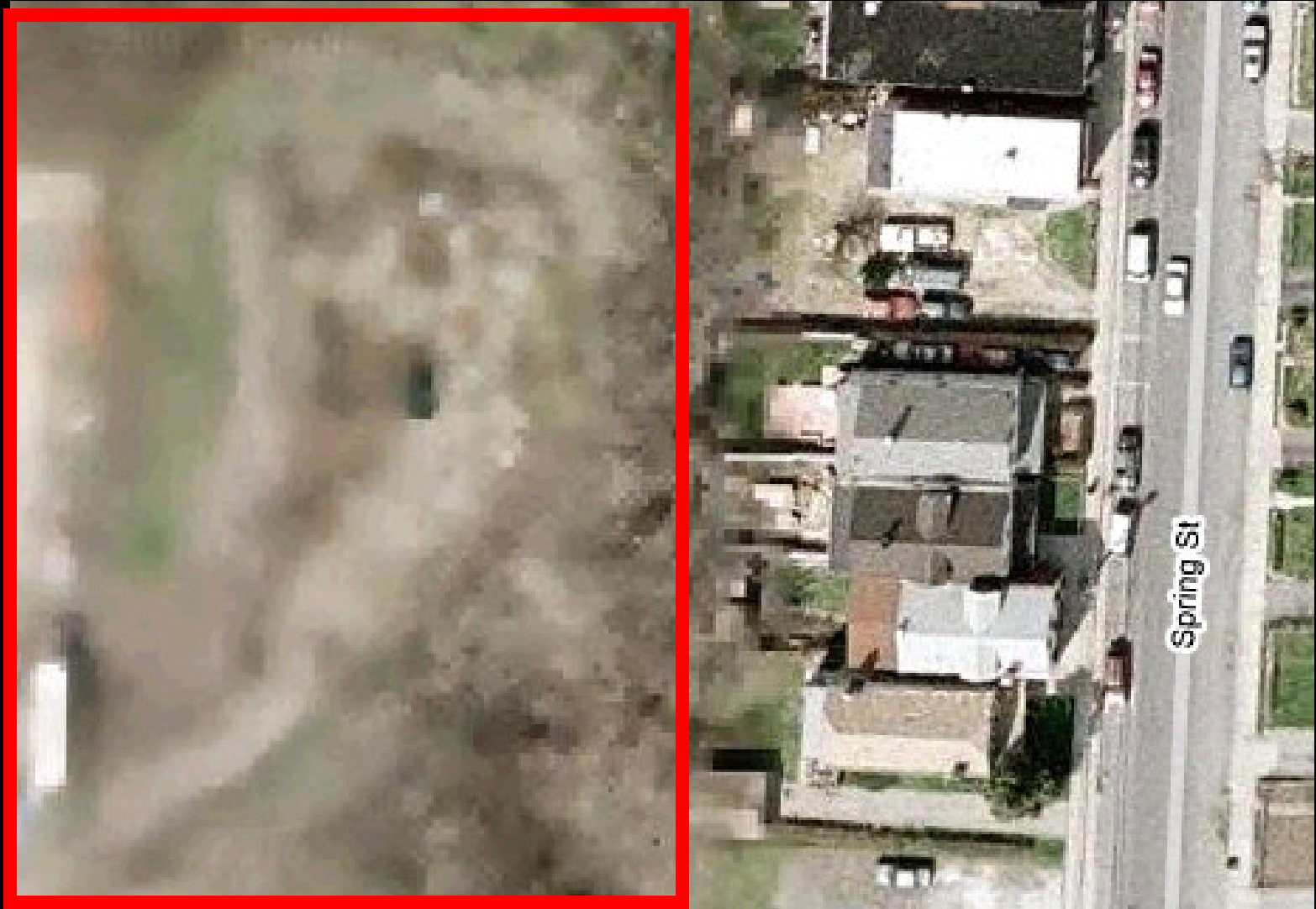
<http://googlesightseeing.com>

Censorship



<http://maps.google.com>

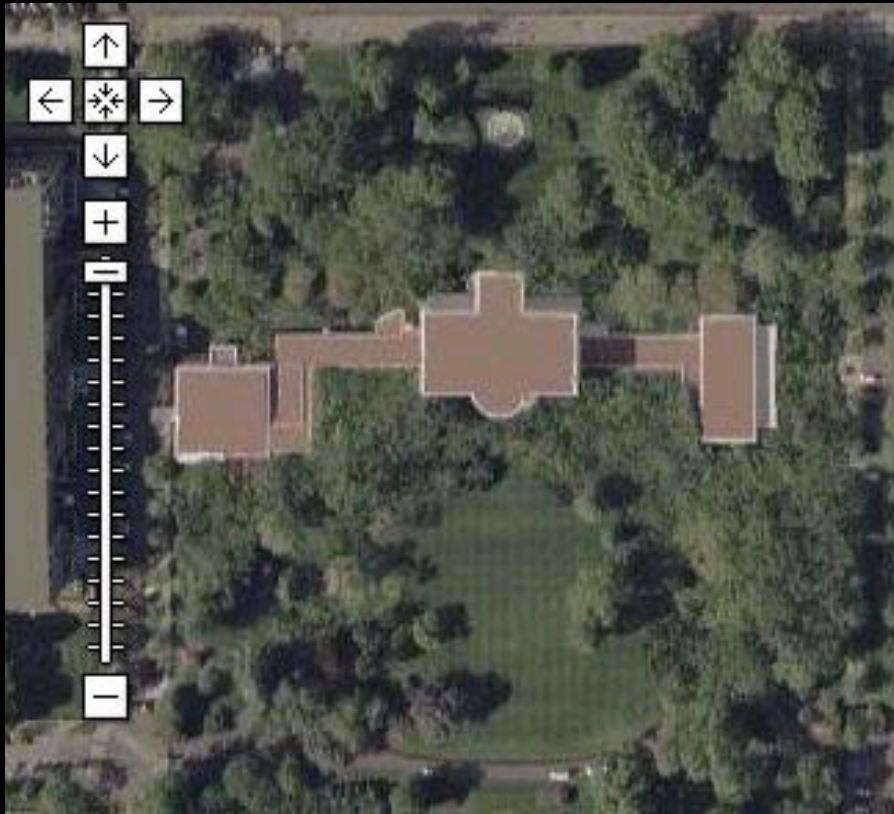
Censorship



Censorship



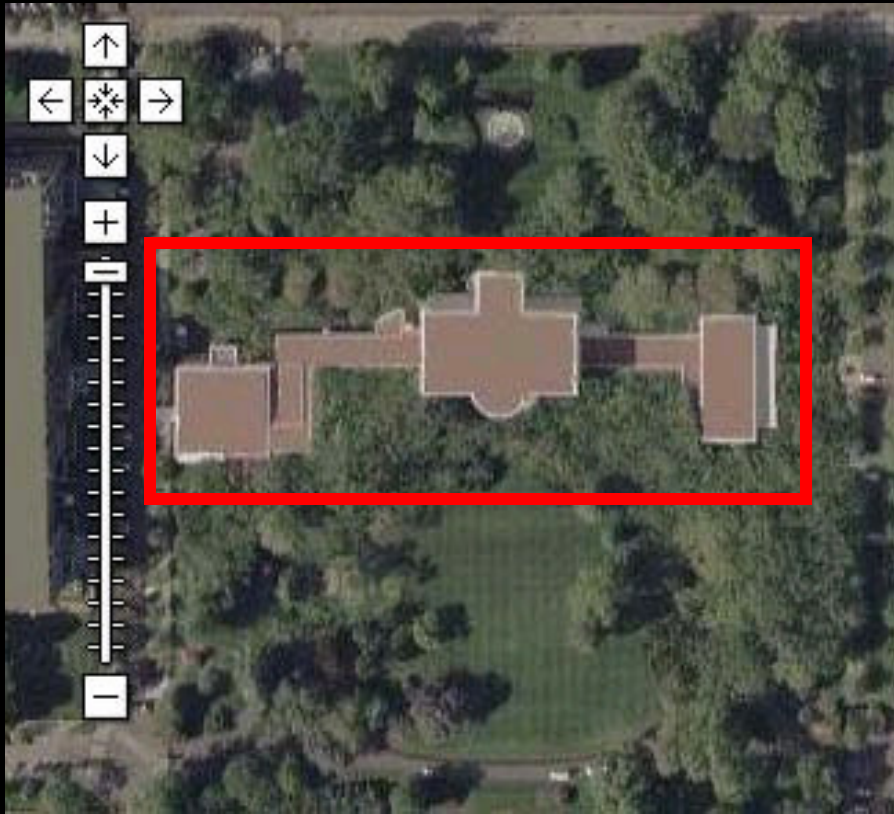
Censorship



http://www.ogleearth.com/2006/01/yes_we_have_no.html

<http://maps.google.com>

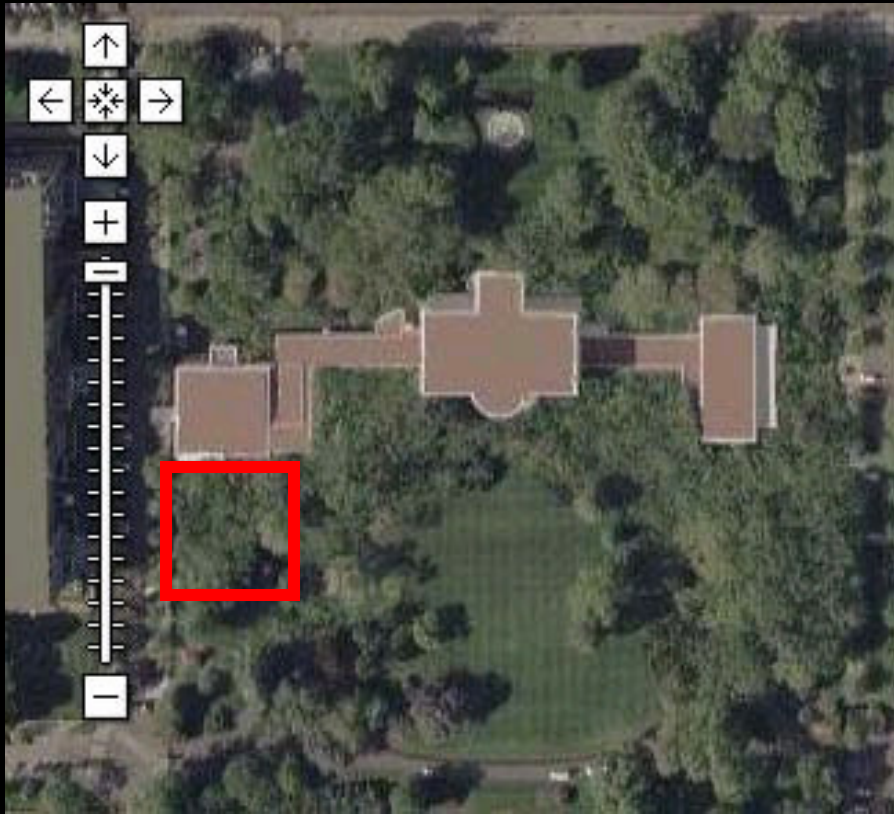
Censorship



http://www.ogleearth.com/2006/01/yes_we_have_no.html

<http://maps.google.com>

Censorship



http://www.ogleearth.com/2006/01/yes_we_have_no.html

<http://maps.google.com>

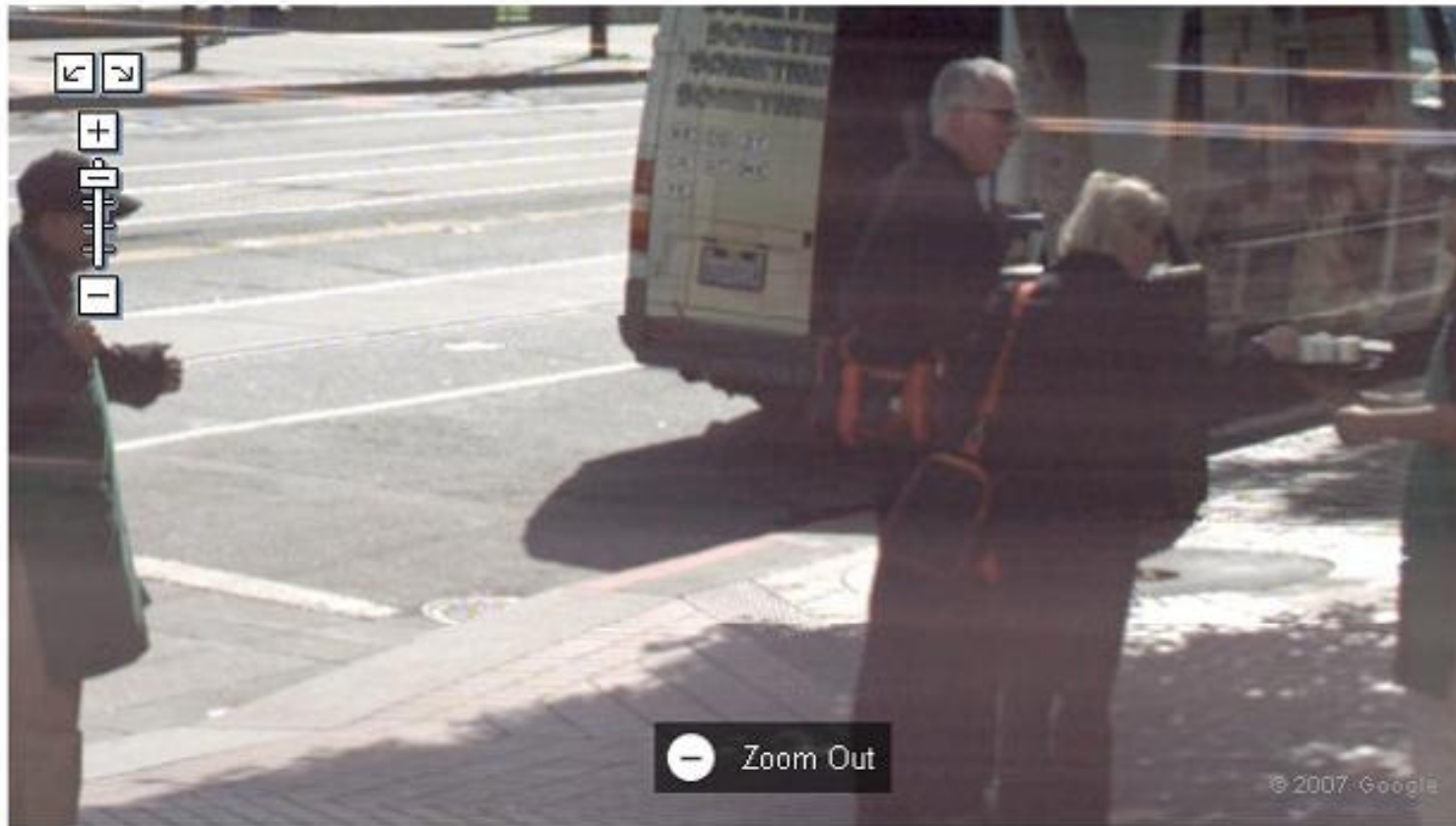
Street Views



16 Market St Address is approximate

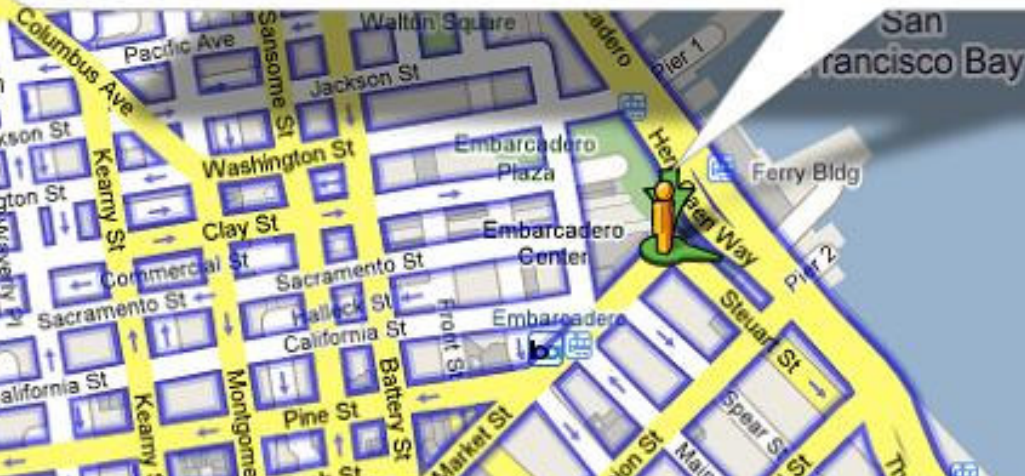
[Street View Help](#)

[Full-screen](#) 



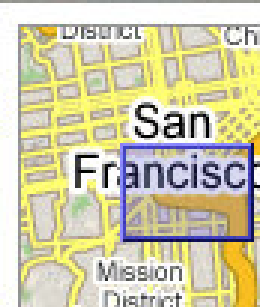
 Zoom Out

© 2007 Google

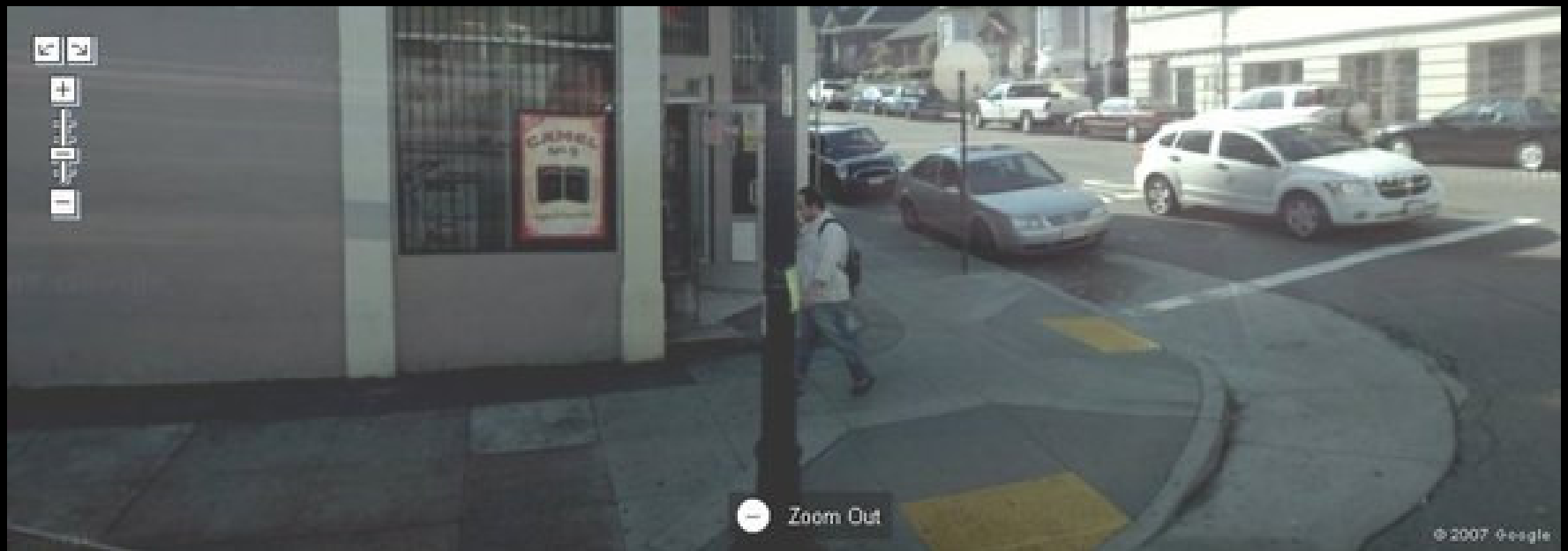


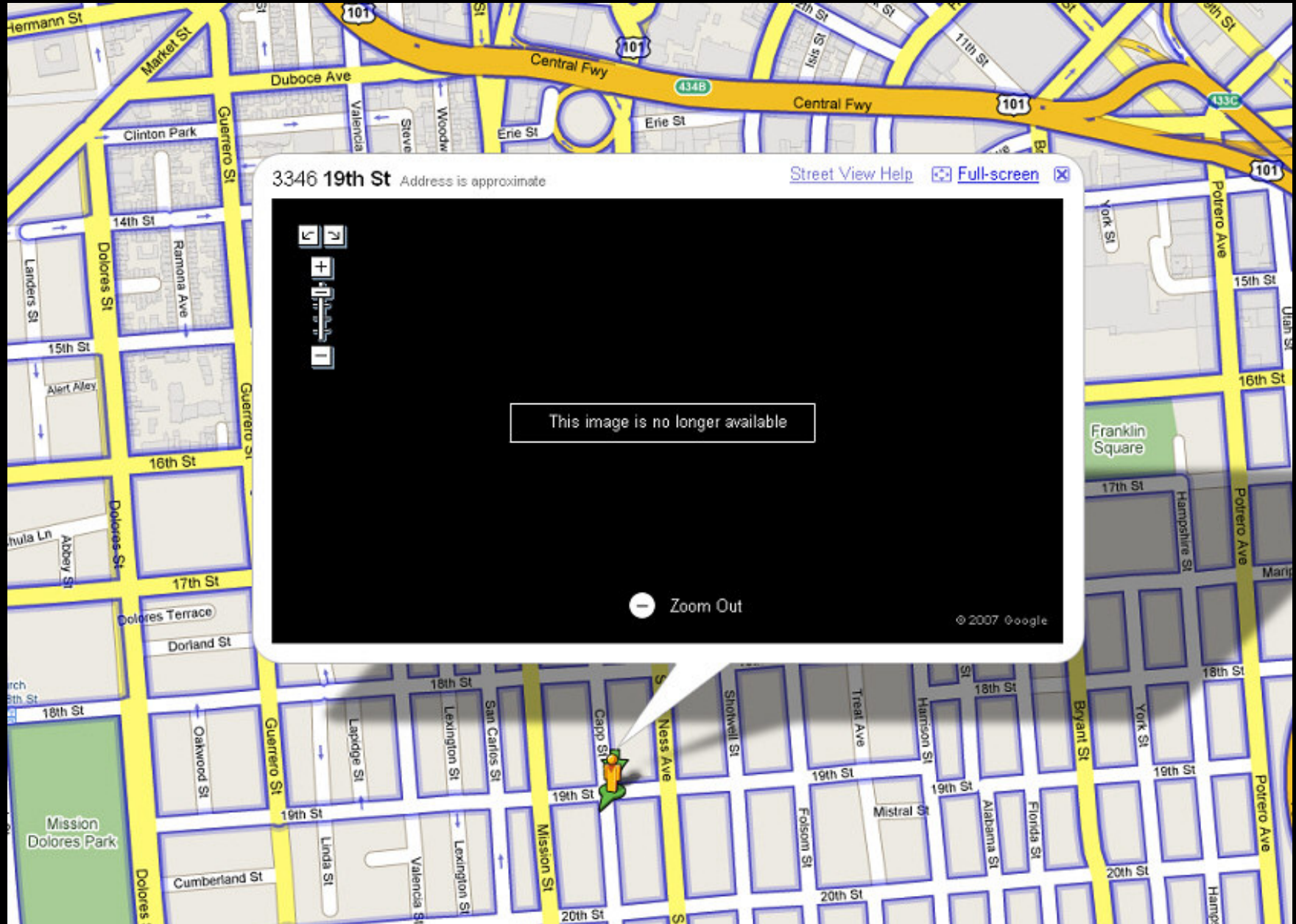
682 S Van Ness Ave Address is approximate

[Street View Help](#) [Full-screen](#)



Be sure to photograph
EFF attorneys too...
(Kevin Bankston)

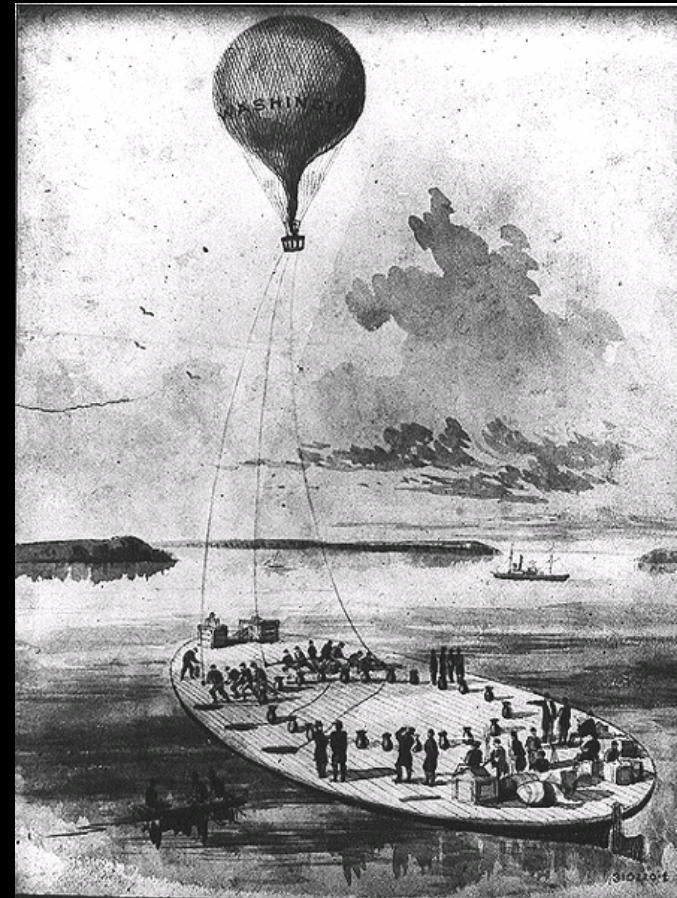




Historical Context

Historical Examples of Aerial Photography

- 1858 (balloon)
 - Gaspar Felix Tournachon
 - Paris
- 1860 (balloon)
 - James Wallace Black
 - Boston
- 1903 (pigeons)
 - Julius Neubronne
- 1906 (kites)
 - George Lawrence
 - San Francisco Earthquake
- 1906 (compressed air rockets)
 - Albert Maul
- 1909 (airplane)
 - Wilbur Wright
 - Centrocelli, Italy
- WWI, WWII ...



Reconnaissance balloon c.1860s

<http://www.aerialarts.com/History/history.htm>

<http://www.centennialofflight.gov/>

Paris 1858

(Gaspar Felix Tournachon - balloon)



San Francisco Earthquake 1906

(George Lawrence - kites)



WWII



RAF WWII vertical aerial photograph
of Leuchars Airfield, Fife.

<http://www.rcahms.gov.uk/aerialphotography.html>

Corona

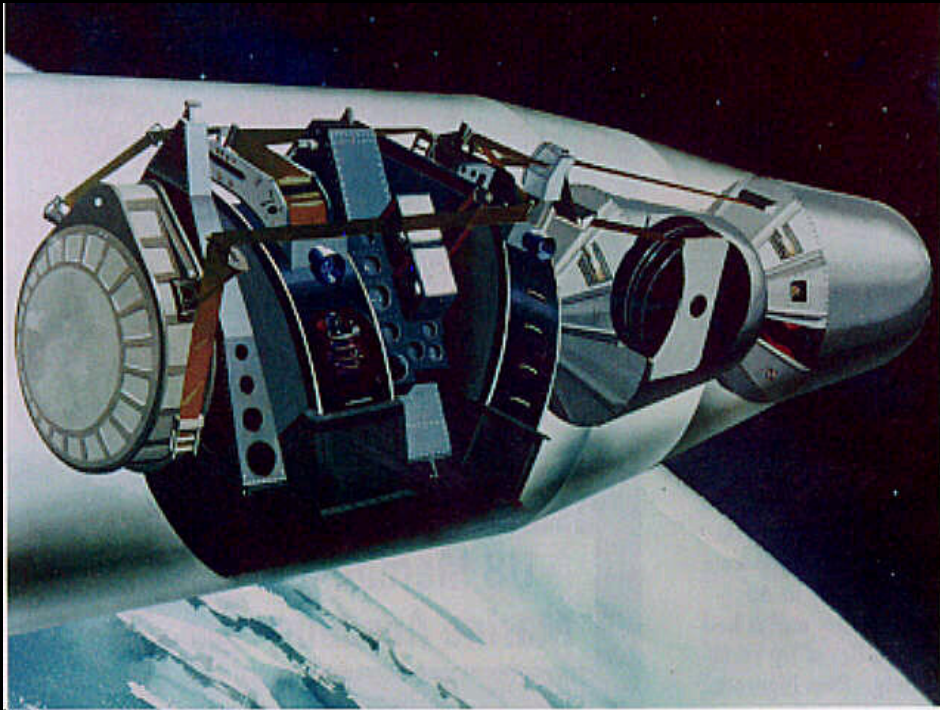
- 1st photo reconnaissance satellite in the world
- Used film canisters
 - Parachute
- Caught mid-air by Aircraft
- Black and White
- Late 1950's - mid 1970's
- Designated (KH-1, KH-2, KH-3, KH-4, KH-4A, KH-4B), Argon (KH-5), Lanyard (KH-6)
 - KH = Keyhole
- Program declassified in 1995
- 25FT - 6FT (~2M) Ground Resolution
- 165KM - 460KM Orbit (LEO)
- 1st stereo-optical data from space
- 800,000+ total images

<http://www.nro.gov/corona/facts.html>

<http://samadhi.jpl.nasa.gov/msl/Programs/corona.html>

<http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=3944>

Corona



Artist's Concept



Thor Agena A

<http://www.nro.gov/corona/artist.jpg>

<http://www.nro.gov/corona/facts.html>

<http://samadhi.jpl.nasa.gov/msl/Programs/corona.html>

<http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=3944>

Corona Imagery 1967



<http://www.nro.gov/corona/corona7.jpg>

Sensor Types



Radar



Electro-optic (visible)

Sensor Types



Radar



Electro-optic (visible)

Sensor Types

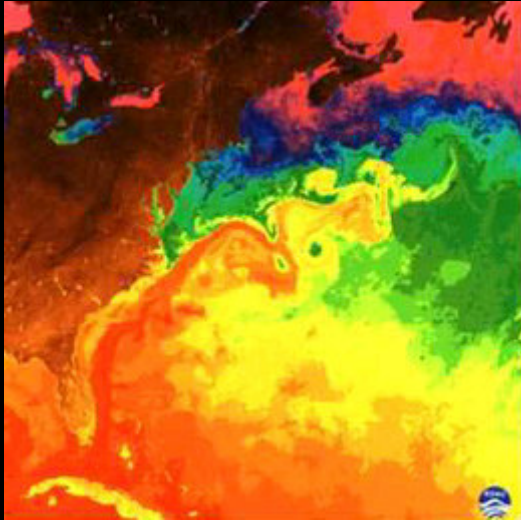


Radar



Electro-optic (visible)

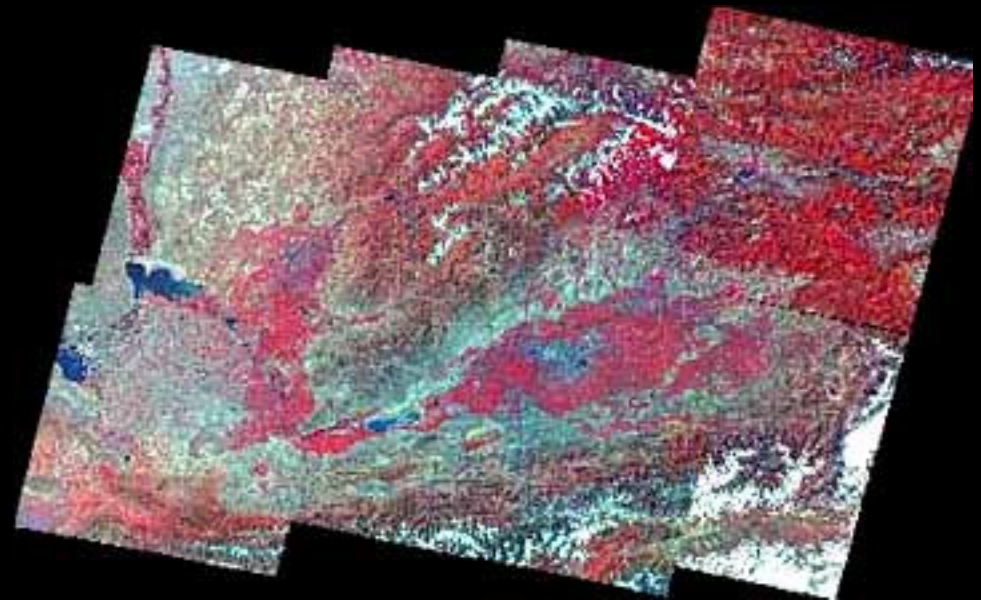
Sensor Types



Thermal



Infrared



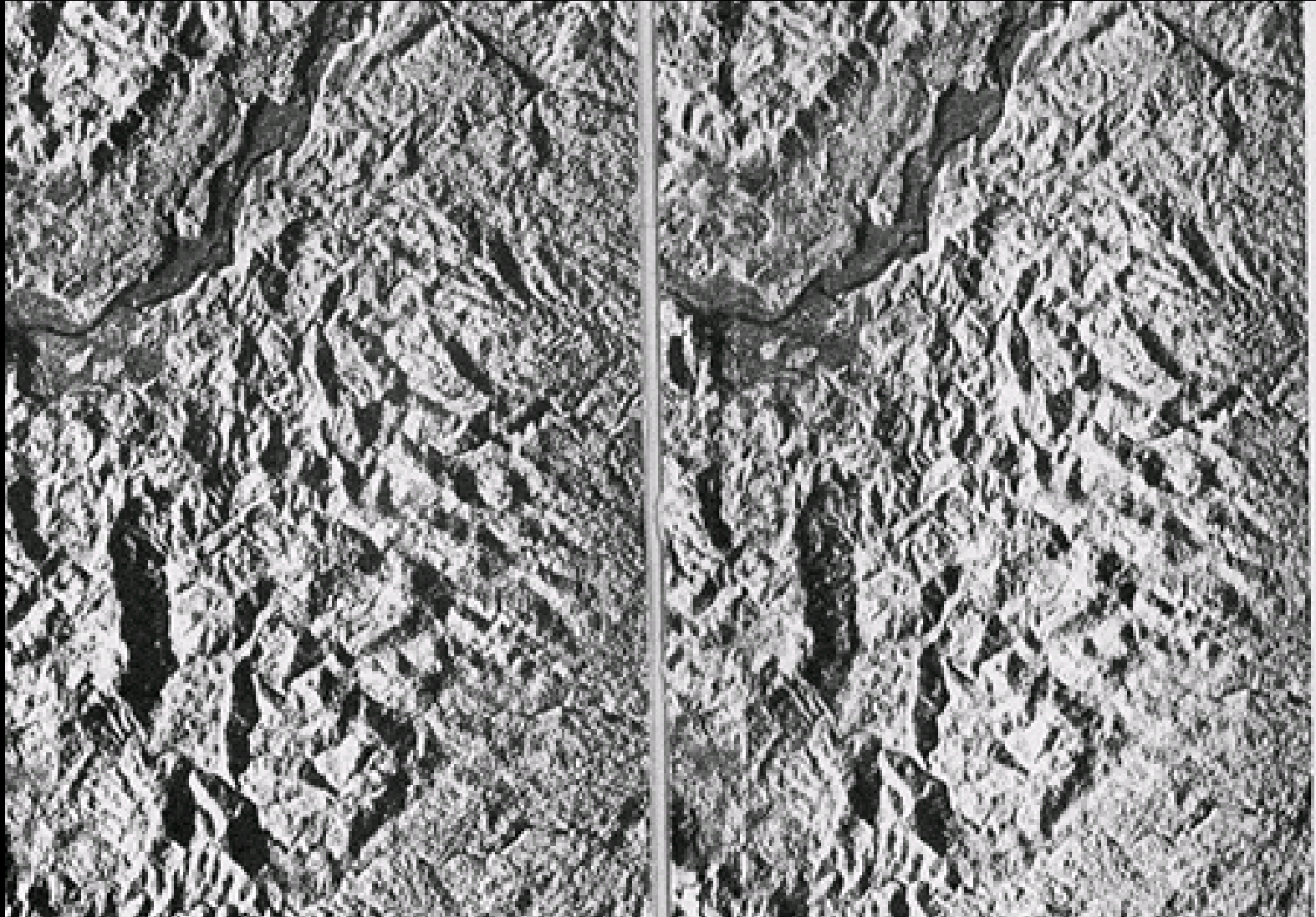
Multispectral

http://rst.gsfc.nasa.gov/Intro/Part2_25.html

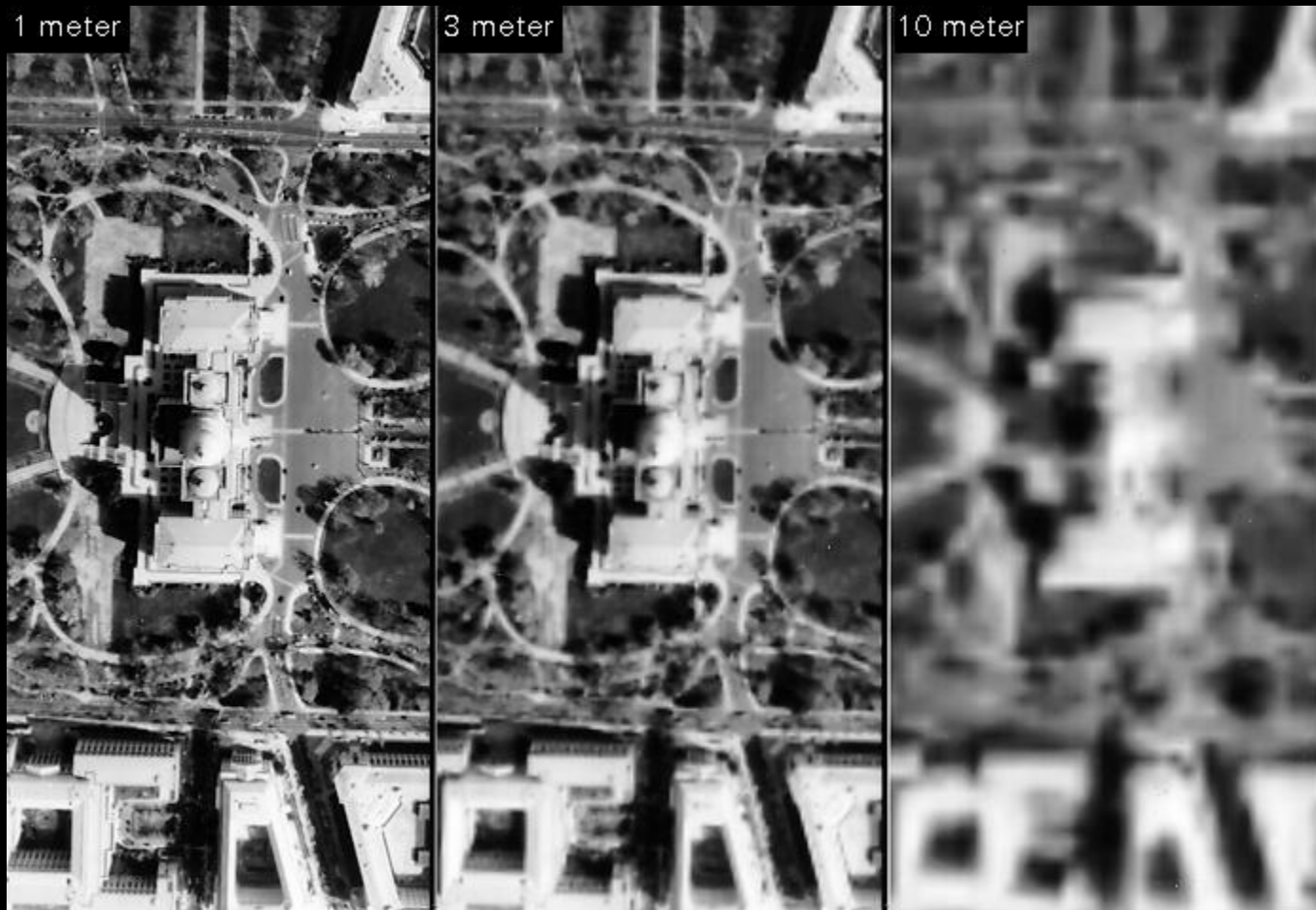
http://rst.gsfc.nasa.gov/Sect8/Sect8_3.html

<http://planning.lacounty.gov/lariac/imgSpInfrared.htm>

Stereo Pairs



Resolution



1 Meter

3 Meter

10 Meter

source: <http://www.fas.org/irp/imint/resolve2.htm>

Sampling Demo

Sensor Platforms

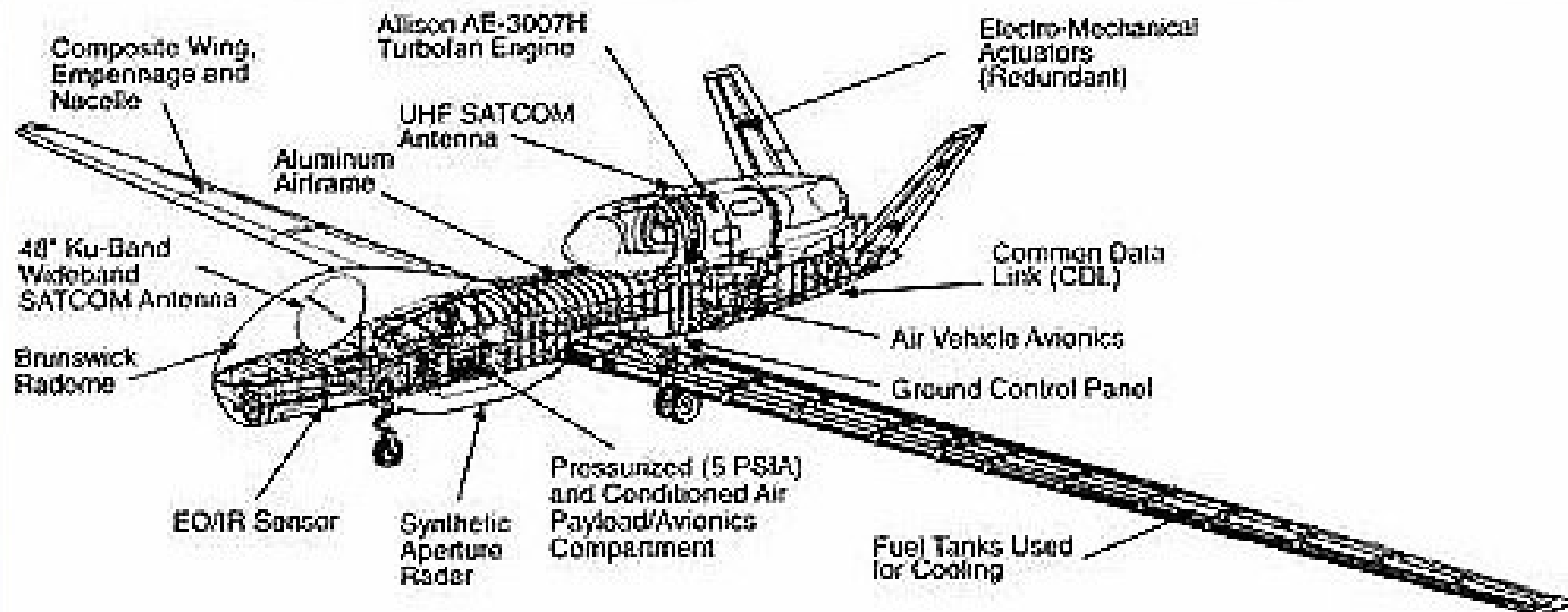
Aircraft



Other Platforms

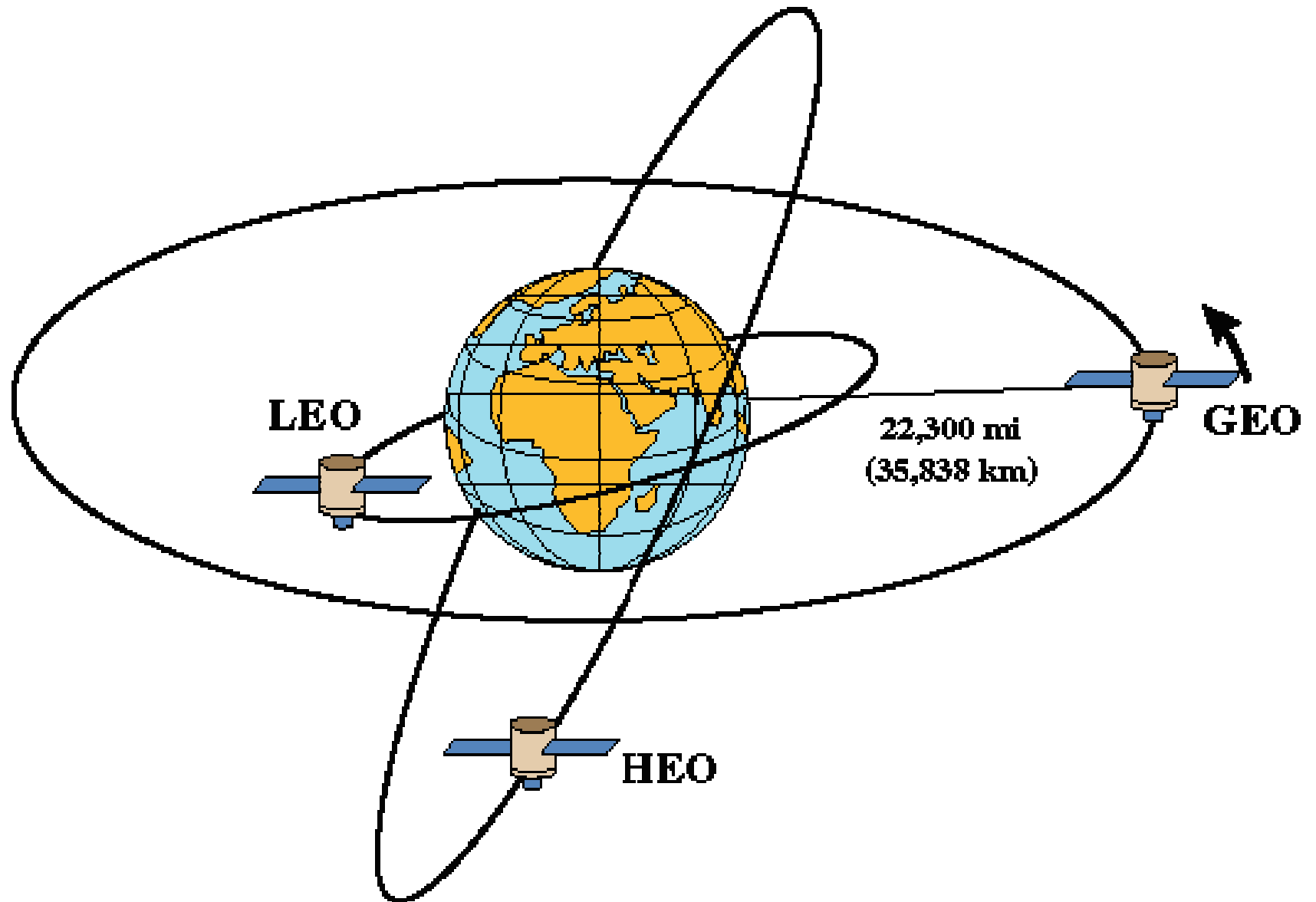


Global Hawk
Source: Teledyne Ryan Aeronautical Inc.

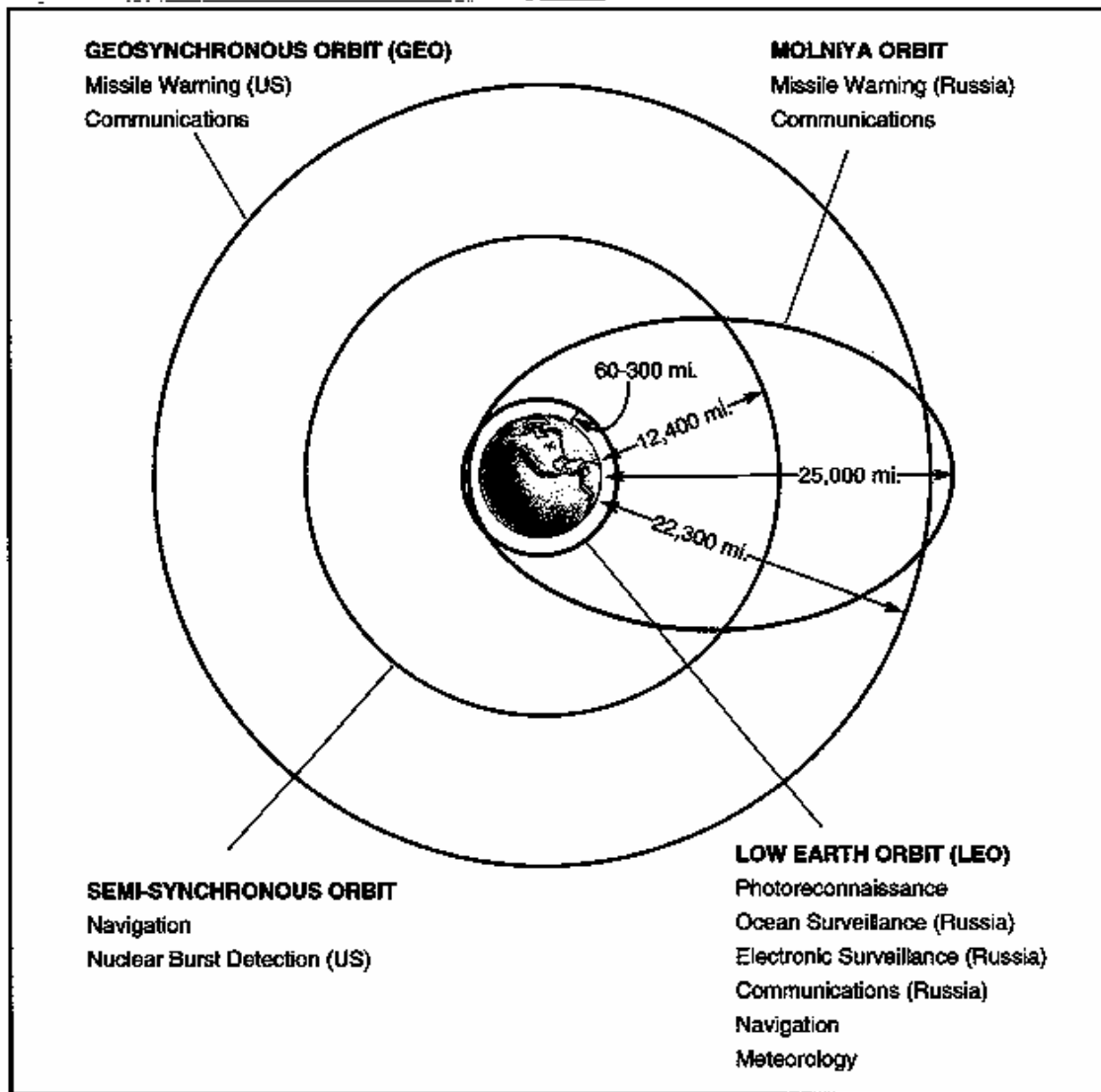


https://wrc.navair-rdte.navy.mil/warfighter_enc/aircraft/UAVs/GHawk.htm

Space Craft Orbits



Typical Satellite Orbits



- **GEO**
 - Missile Warning (US)
 - Communications
- **HEO**
 - Missile Warning (Russia)
 - Communications
- **LEO**
 - Photorecon
 - Ocean surveillance
 - Communications
 - Navigation
 - Meteorology

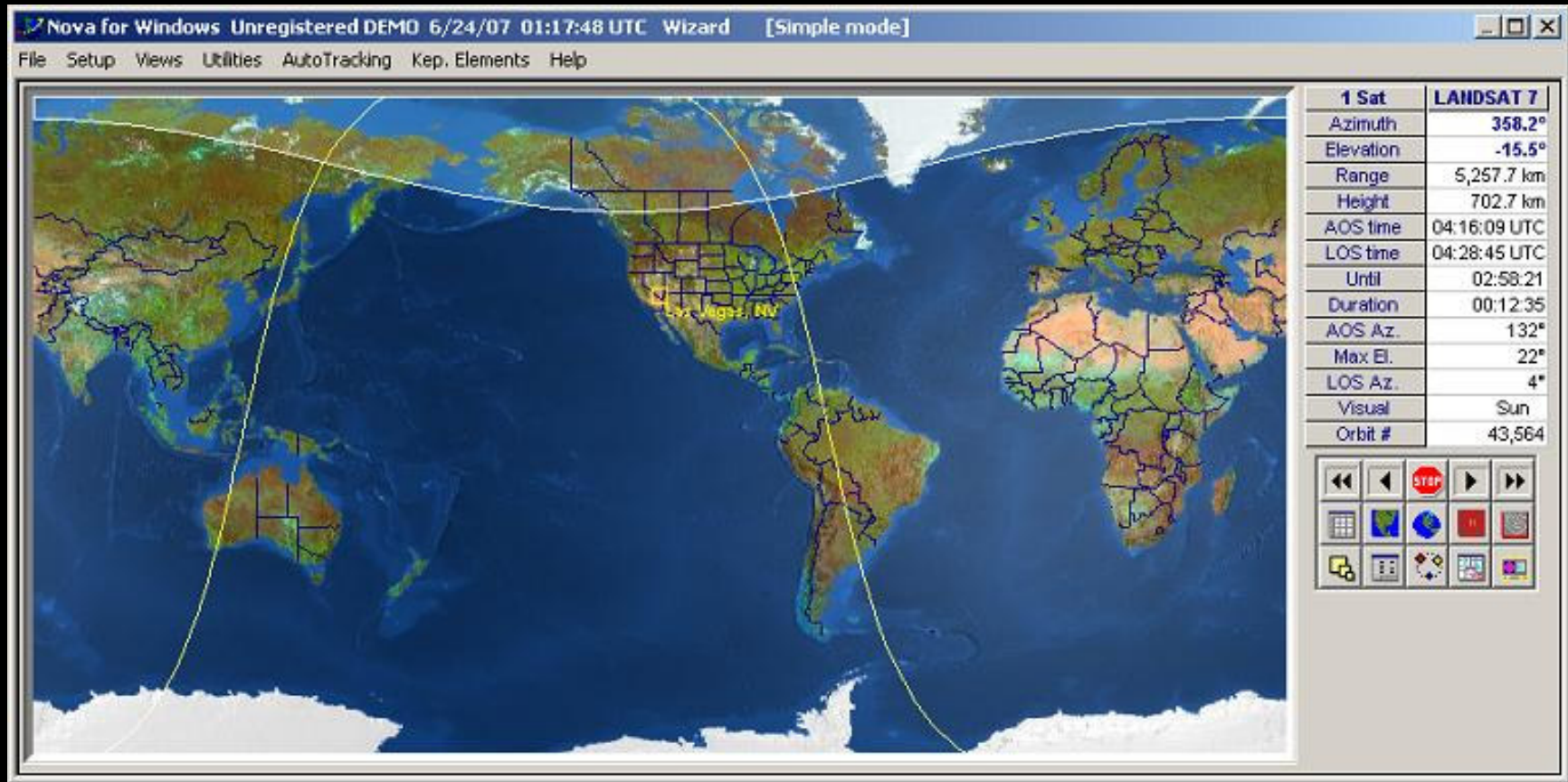
Adapted from "Satellites and Anti-Satellites" by Ashton B. Carter, *International Security*, Spring 1988.

Keplerian Elements

- Epoch
- Orbital Inclination
- Right Ascension of Ascending Node
- Argument of Perigee
- Eccentricity
- Mean Motion
- Mean Anomaly
- Drag (optional)

*Keplerian elements are the inputs to a standard mathematical model of spacecraft orbits. Combined with the correct time and station location you can compute when the satellite will be in view and where to point your antennas.
[www.amsat.org]*

Example of Imagery Satellite Keps



Analysis

Methodology

- NIIRS
- Orient
- Locate
- Identify
- Uniquely Identify (if possible)
- Build domain knowledge

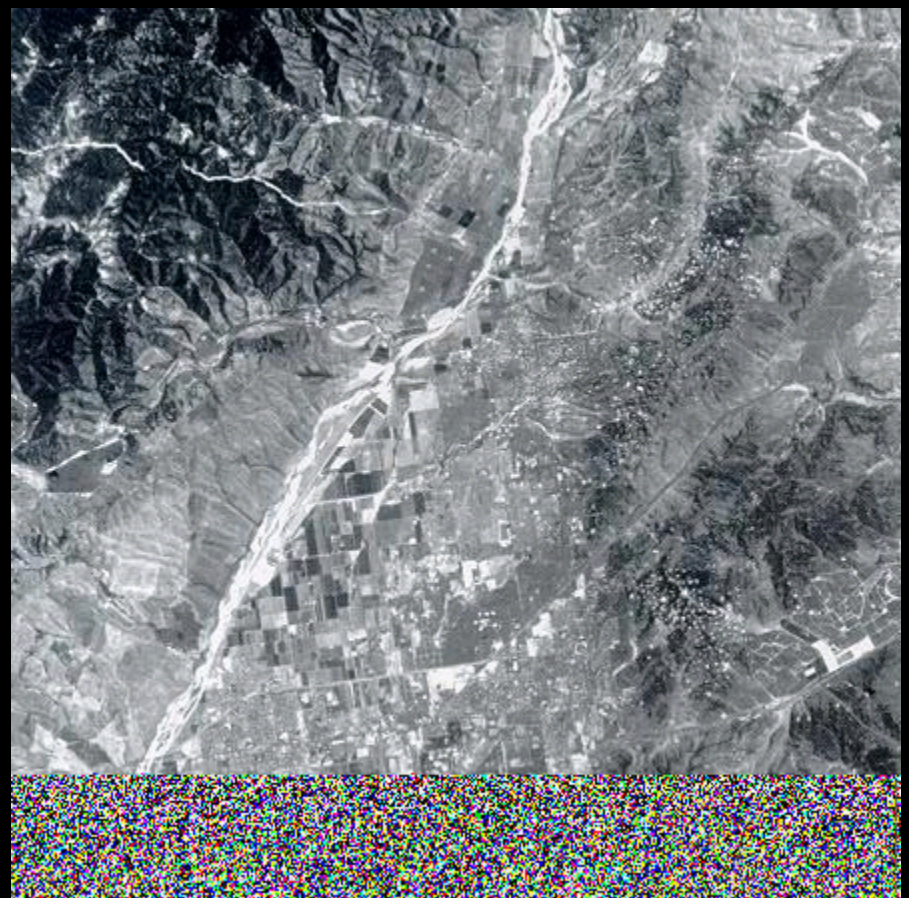
National Imagery Interpretability Rating Scale (NIIRS)

- A rating from 1-9
 - 1 bad to 9 best
- Sets reasonable expectations
- Allows comparison



NIIRS 1

Detect a medium-sized port facility



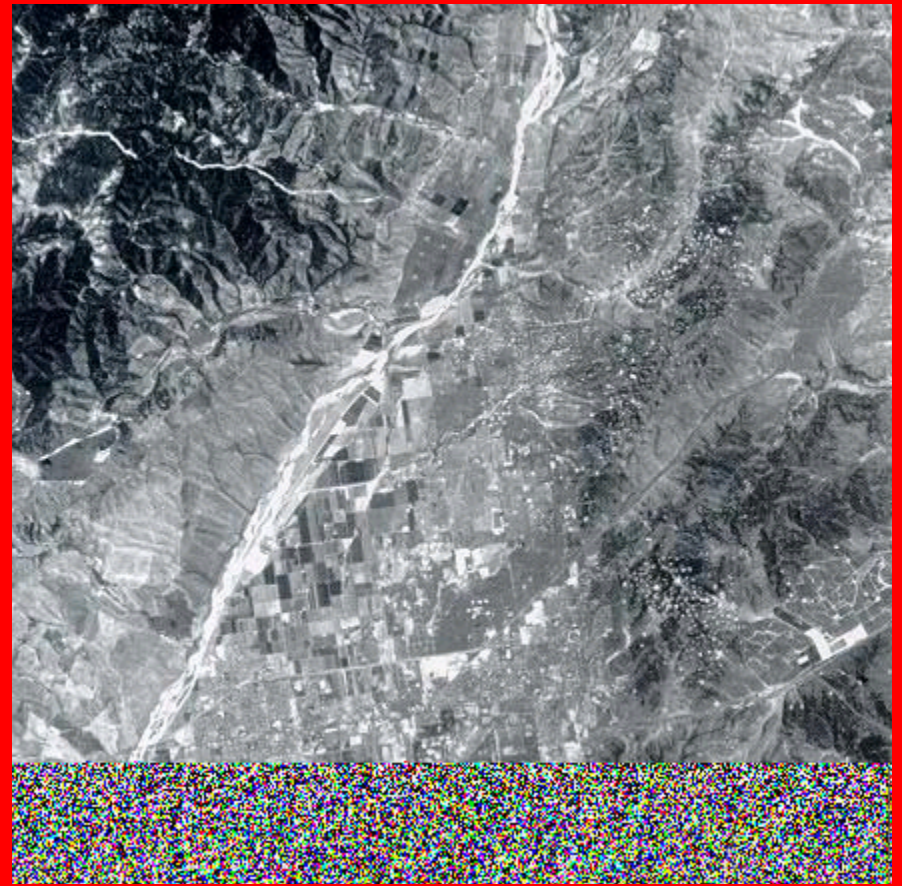
NIIRS 2

Detect large hangars at airfields



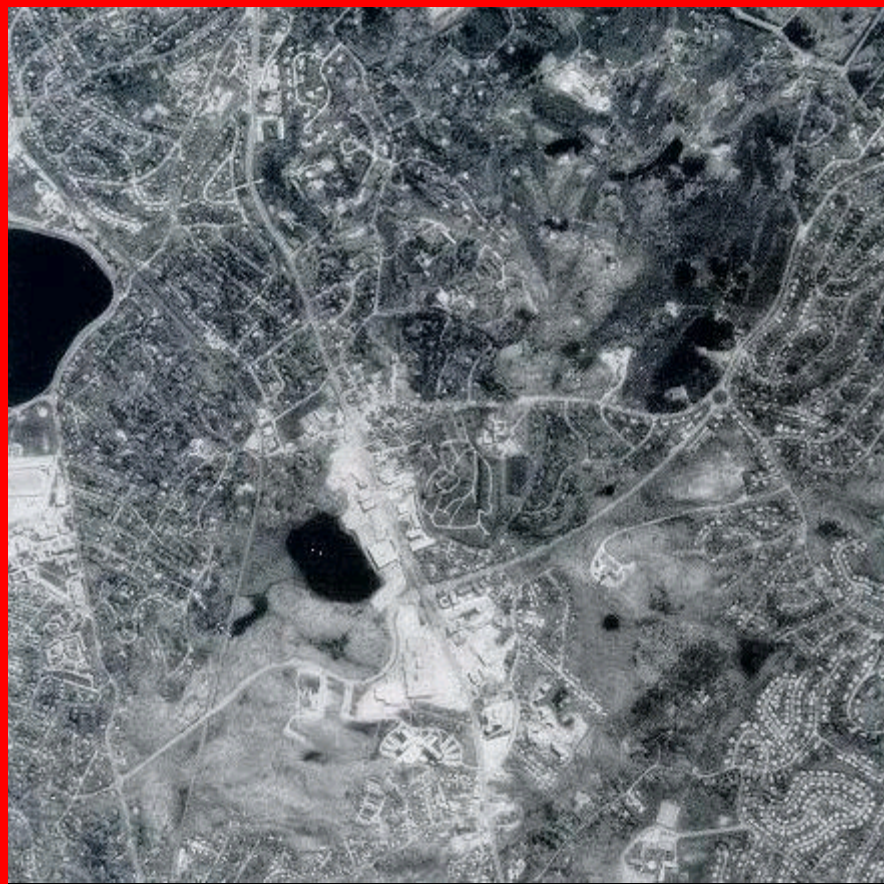
NIIRS 1

Detect a medium-sized port facility



NIIRS 2

Detect large hangars at airfields



NIIRS 3

Detect individual houses



NIIRS 4

Identify all large fighters by type
(e.g. F-15, F-14)

www.fas.org/irp/imint/niirs.htm



NIIRS 3

Detect individual houses



NIIRS 4

Identify all large fighters by type
(e.g. F-15, F-14)

www.fas.org/irp/imint/niirs.htm



NIIRS 5

Identify radar as
vehicle-mounted or
trailer-mounted



NIIRS 6

Identify the spare
tire on a medium-
sized truck



NIIRS 5

Identify radar as
vehicle-mounted or
trailer-mounted



NIIRS 6

Identify the spare
tire on a medium-
sized truck



NIIRS 7

Identify ladder
on RV



NIIRS 8

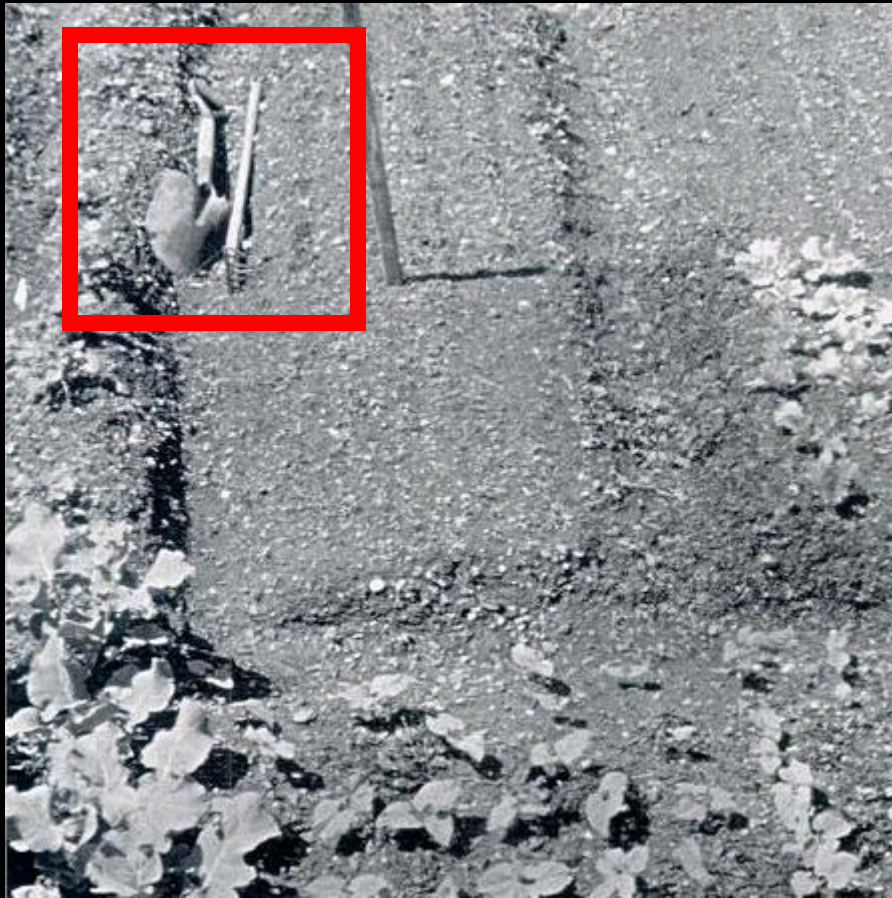
Identify windshield
wipers on a vehicle



NIIRS 7
Identify ladder
on RV



NIIRS 8
Identify windshield
wipers on a vehicle

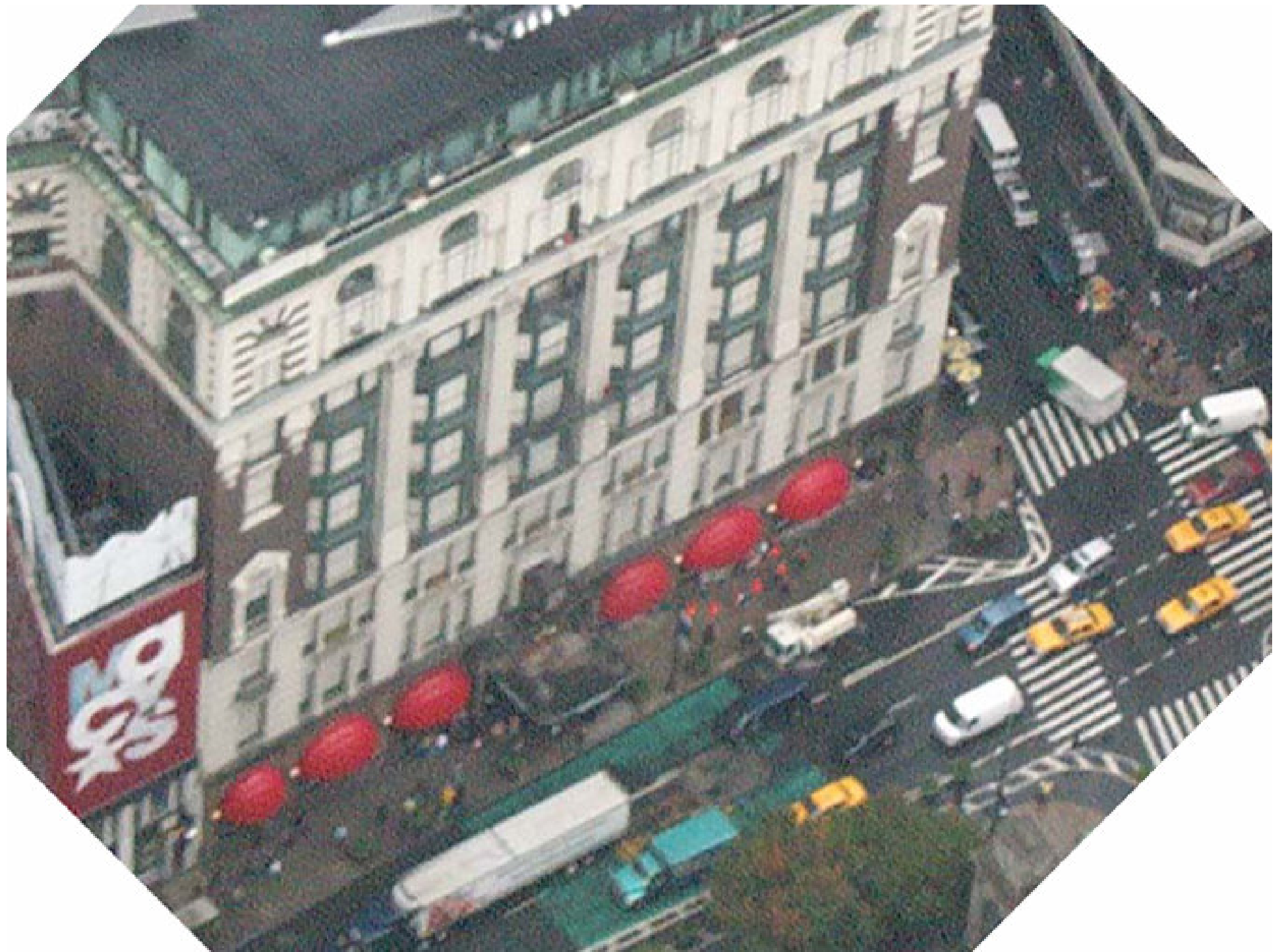


NIIRS 9

Detect individual
spikes in railroad
ties

Rotate Image to Vantage Point of Observer

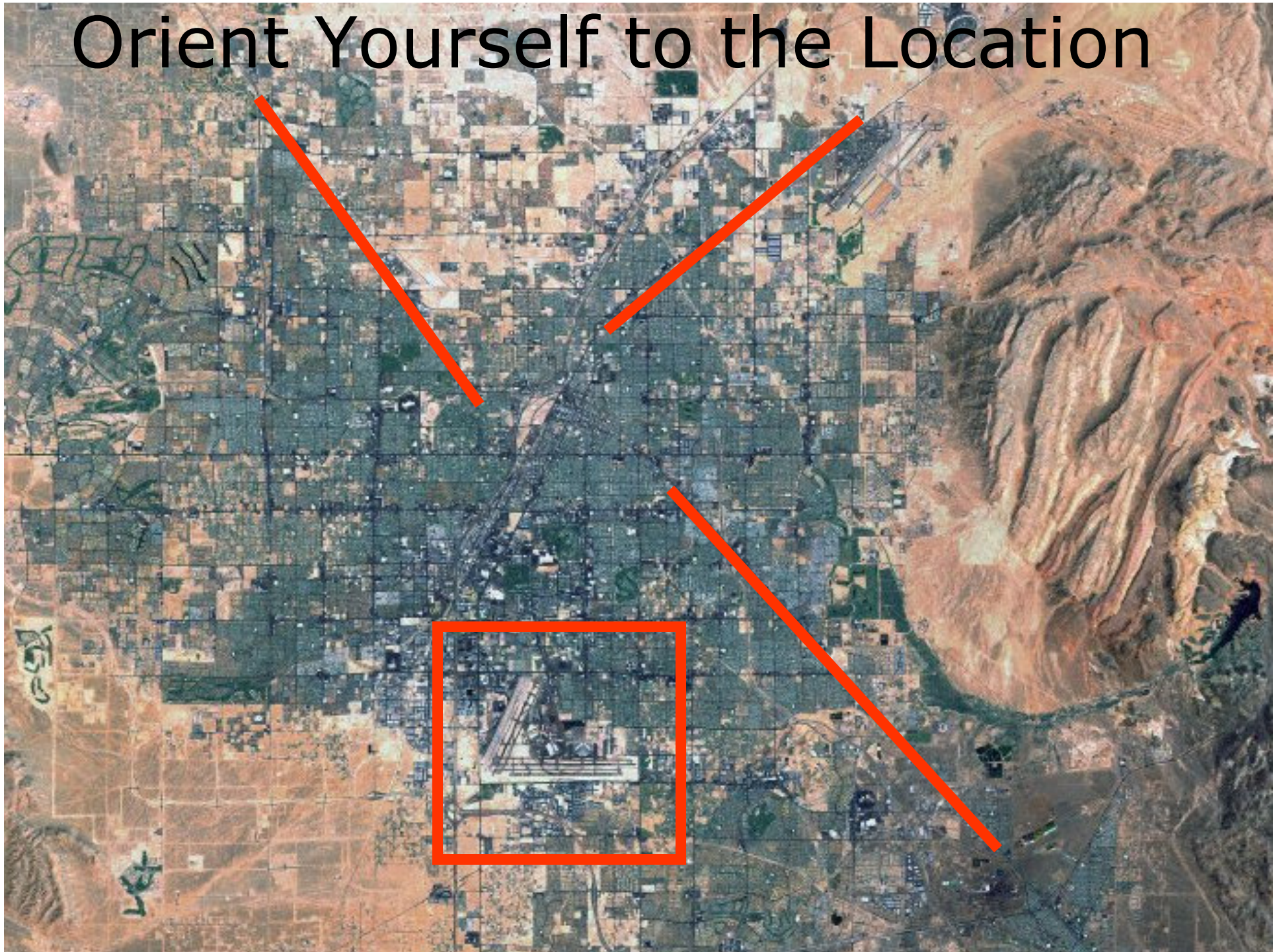




Analysis Characteristics

- Context
- Shape
- Time / Date
- Orientation
- Power source
- Transportation
- Unique characteristics
- Size
- Use
- Anomalies
- Patterns
- Surrounding area
- Outliers

Orient Yourself to the Location

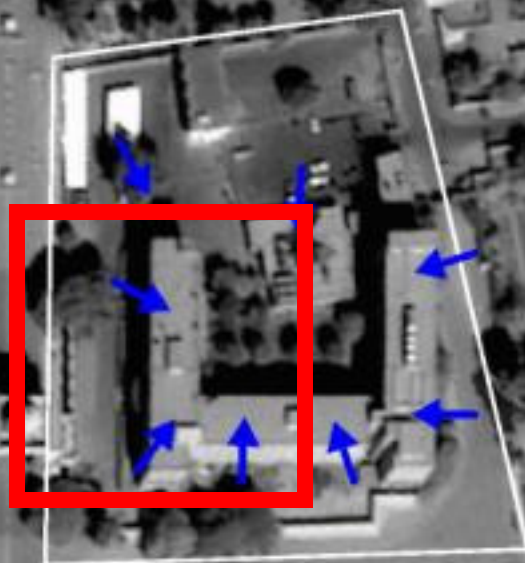


SPECIAL SECURITY OFFICES, BAGHDAD
PRE STRIKE

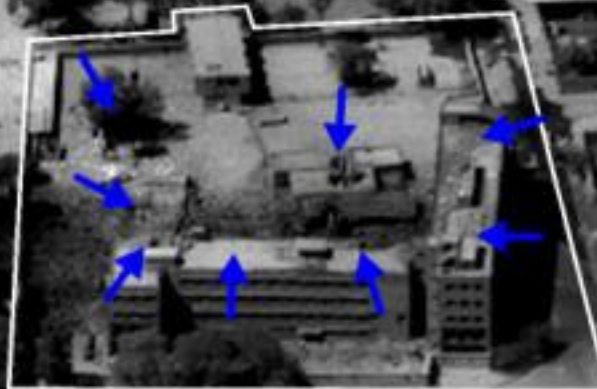


Comparison over time

SPECIAL SECURITY OFFICES, BAGHDAD
PRE STRIKE

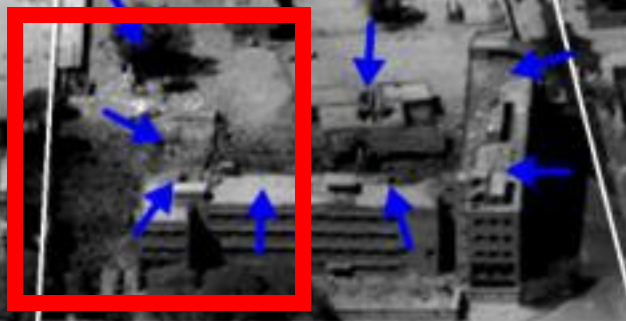


SPECIAL SECURITY OFFICES, BAGHDAD
POST STRIKE



KT142591

SPECIAL SECURITY OFFICES, BAGHDAD
POST STRIKE



KT142591

Look for Cultural Indicators









Parking



Parking



17 MARCH 2003

**LOADING ACTIVITY
LATIFIYA (AL QA QAA), IRAQ**



 **TRUCK**
 **HEAVY EQUIPMENT TRANSPORTER**

Transloading

TI617576

Reverse Engineering

Reverse Engineering a (Sim)City

- Roads
- Railroads
- Seaports
- Tunnels
- Classes of roads, bridges...
- Subways
- Residential areas
- Commercial areas
- Industrial areas
- Police
- Fire stations
- Hospitals
- Water / water treatment
- Power plants/grid
- Garbage disposal
- Recycling centers
- Stadiums
- Zoo
- Colleges
- Libraries
- Prisons
- Population
- Crime
- Communication facilities
- Farms mines quarries
- Warehouses
- Refineries

<http://webdevelopersjournal.com/gifs/simcity1.gif>

<http://www.slideshare.net/wuzziwug/city-building-games/>

<http://209.85.165.104/search?c=cache:IEvWxWkUSQJ:www.asce.org/reportcard/2005/fullreport.cfm%3Fid%3D5+%22power+grid%22+water+roads&hl=>

Smart Book & Identification

Antennas



Yagi



Cell Towers



Microwave



Parabolic Reflector / Satellite Dish

Bridging



Trestle Bridge



Arch Bridge



Bridge Under Construction



Draw Bridge

Aircraft Identification



Cessna Citation II



Gulfstream IV



Lockheed WP-3D Orion



Lake Seawolf (LA-27)

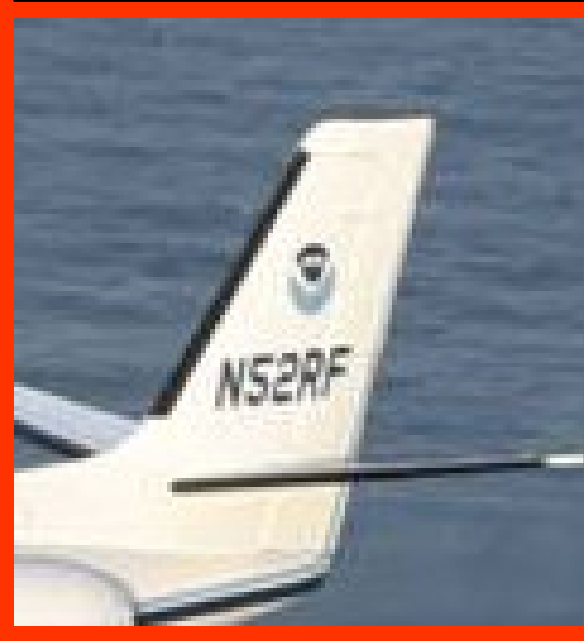
<http://www.aoc.noaa.gov/>

Unique Aircraft Identification



N-number inquiries: http://registry.faa.gov/aircraftinquiry/NNum_inquiry.asp

Unique Aircraft Identification



UNITED STATES DEPARTMENT OF
COMMERCE

NOAA AIRCRAFT OPERATIONS
CENTER
7917 HANGAR LOOP DR HANGAR 5
MACDILL AFB, FLORIDA 33621-5401

Serial Number	550-0021
Type Registration	Government
Manufacturer Name	CESSNA
Certificate Issue Date	01/26/1988
Model	550
Status	Valid
Type Engine	Turbo-Jet
MFR Year	1978

N-number inquiries: http://registry.faa.gov/aircraftinquiry/NNum_inquiry.asp

Kazan Helicopter Plant



MiG-35 at Aero India Airshow

Aero India 2007 News, Daily Aero India 2007 Show Coverage, Photos, Videos – Defense News – Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.defensenews.com/aero/video.php?id=29

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Middle East & Africa

Reference & Opinion
Links & Documents
Event Calendar
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TSJ
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AERO INDIA

6TH INTERNATIONAL AEROSPACE & DEFENCE EXHIBITION—2007 FEB 7-11



MiG-35 at Aero India
The MiG-35 is seen in action at Aero India 2007

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MORE VIDEO FROM AERO INDIA

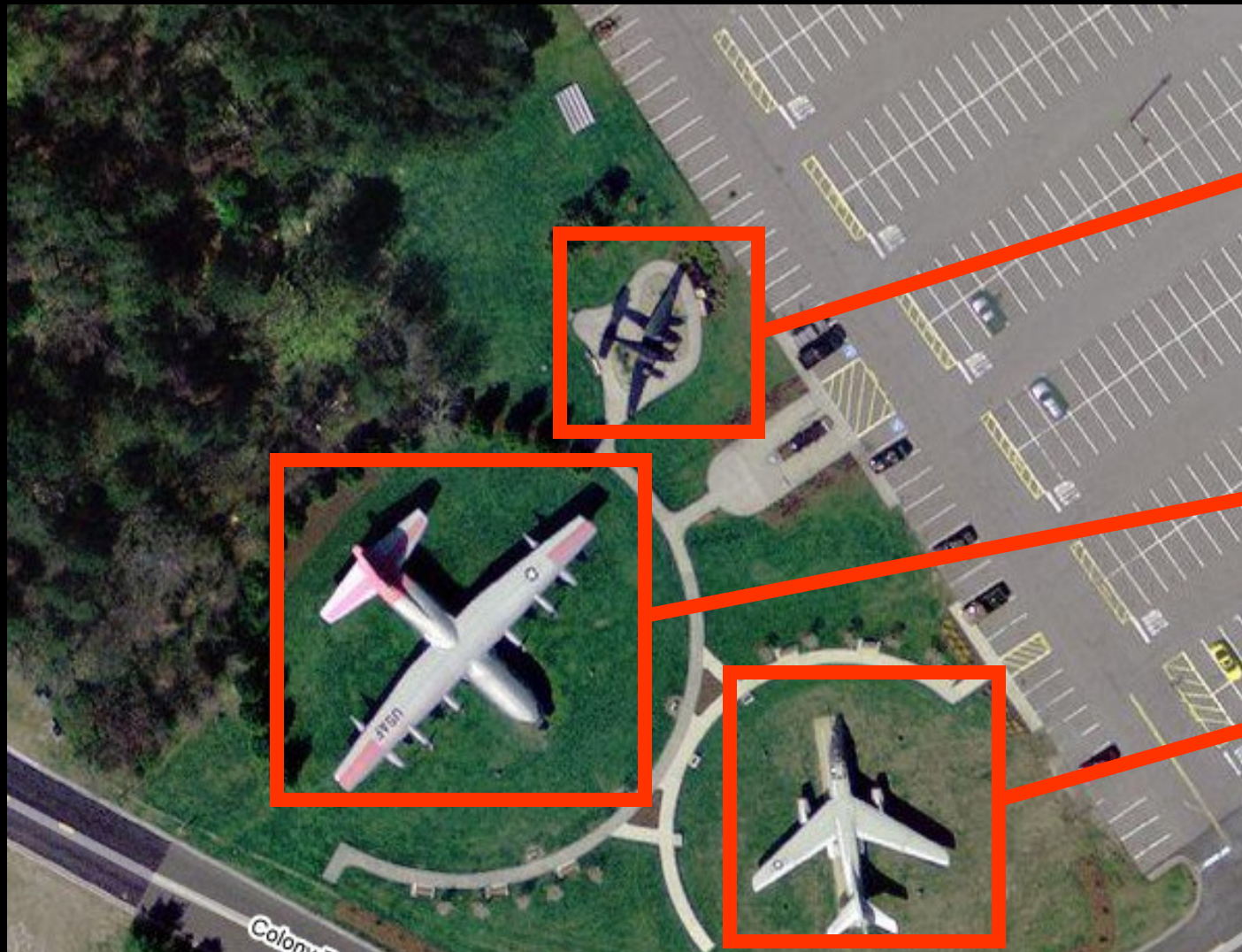
Friday, February 9 »
VIDEO CH-47 heavy lift helicopter
GALLERY Photos from Day 3

Thursday, February 8 »

Transferring data from www.defensenews.com...

Skill Building

Museums



RU-8D Seminole

Reconnaissance
Configured C-130

EA-3B Skywarrior

Graveyards...



Aircraft Flights...



Seaport Rides...



<http://www.maine.gov/>

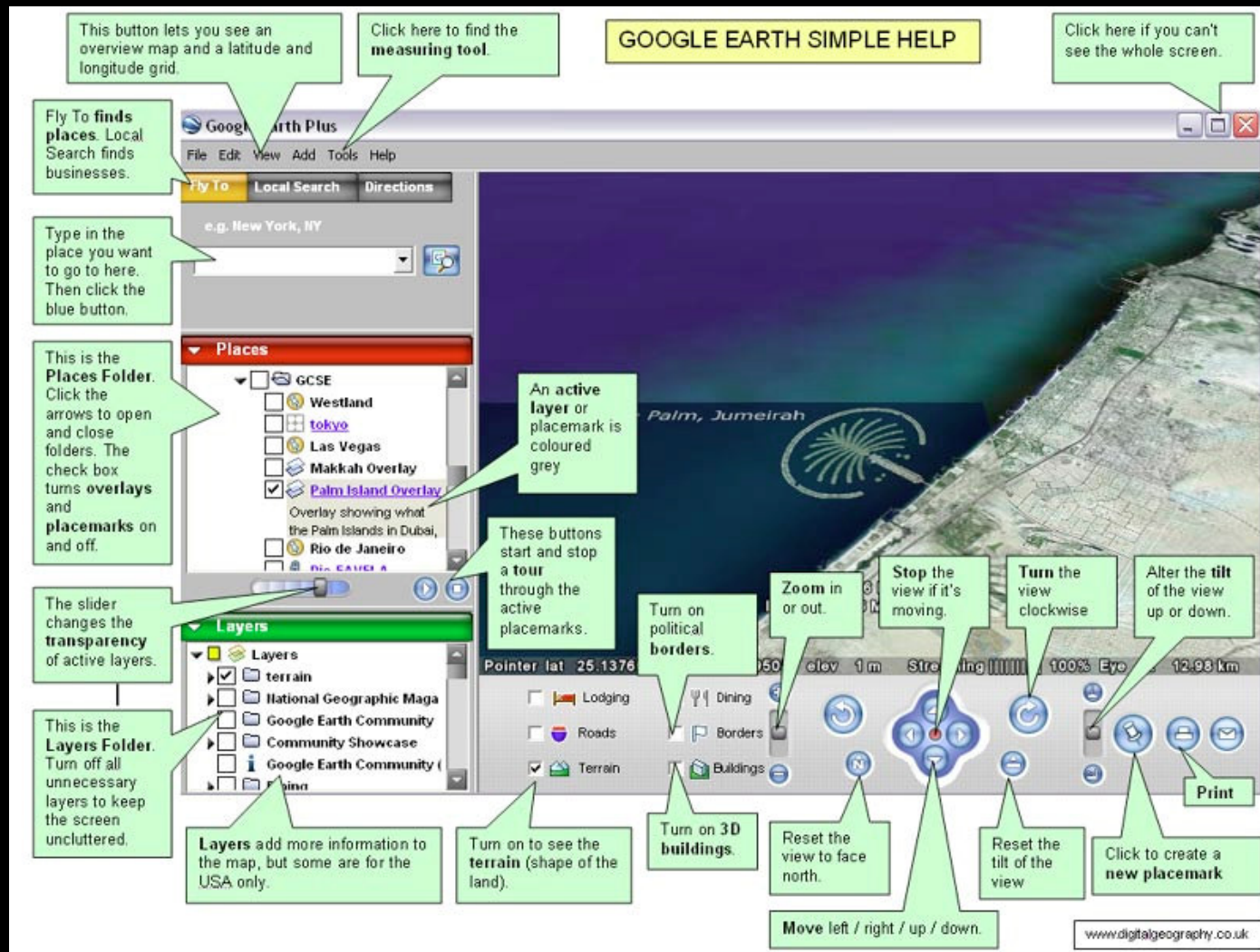
Collaborative Analysis

Wikimapia.org

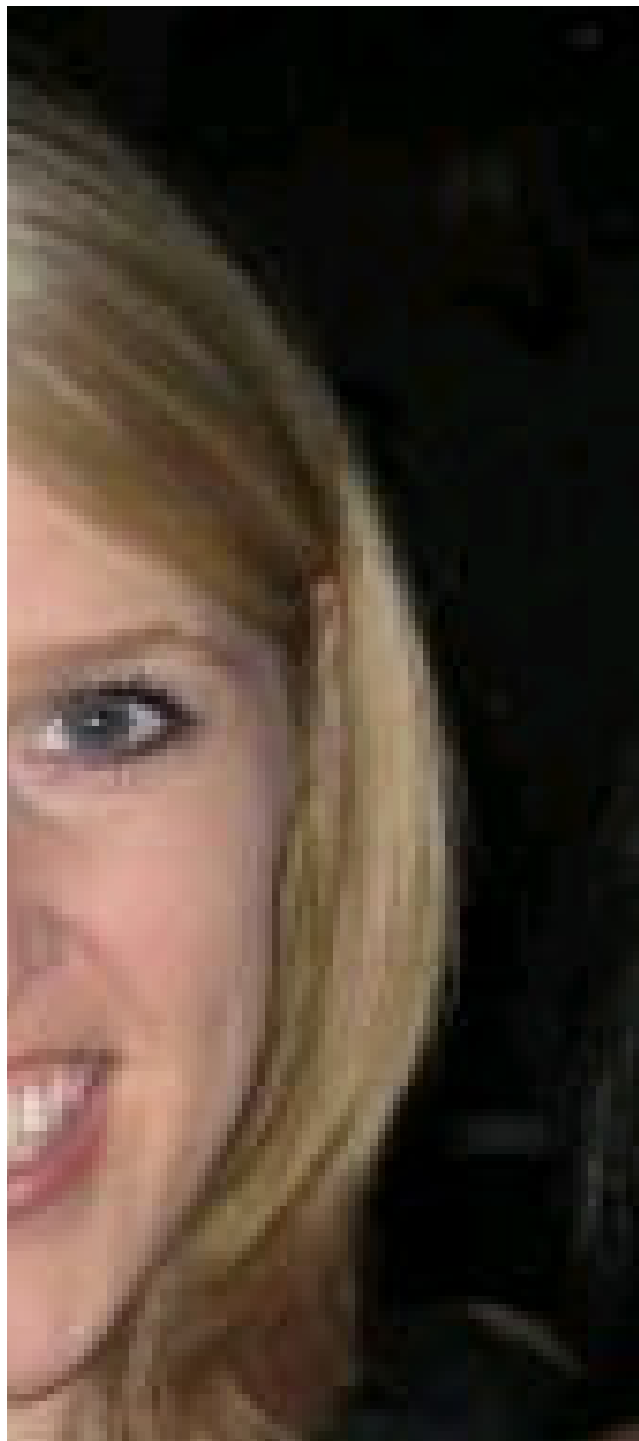


Learn the tools

Google Earth Visual Guides

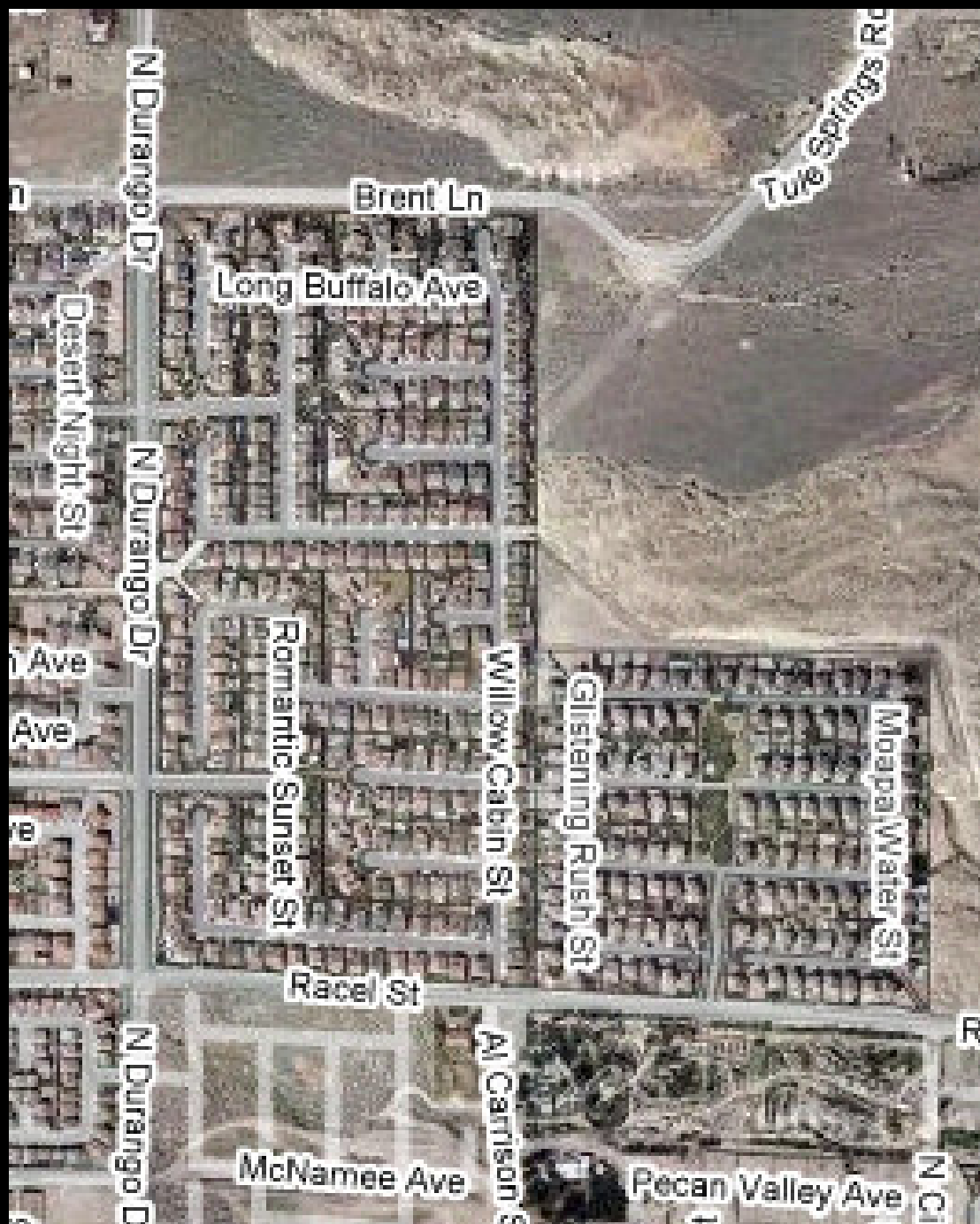


<http://www.digitalgeography.co.uk/archives/2006/03/google-earth-visual-guide>

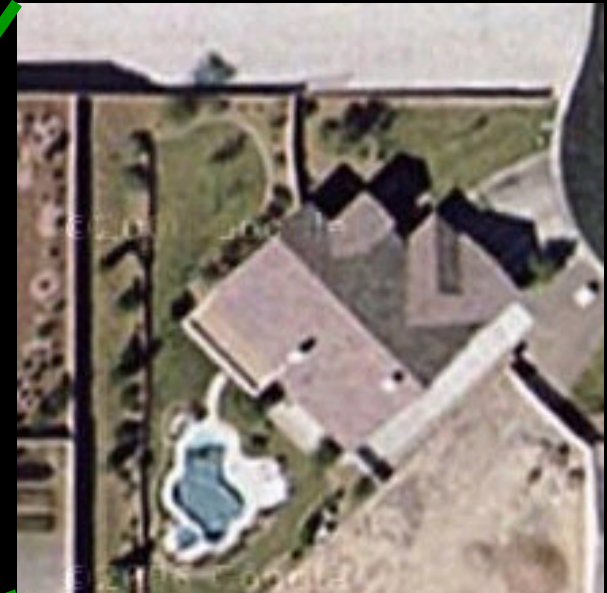


Watching the Watcher...

<http://blogs.zdnet.com/Ou/?p=653>







More Information

- Google Sightseeing
<http://googlesightseeing.com/>
- Google Earth Blog
<http://www.earthblog.com/>
- Wikimapia
<http://wikimapia.org>
- Cryptome Eyeball Series
<http://eyeball-series.org/>
- Google Earth Visual Guides
<http://www.digitalgeography.co.uk/archives/2006/03/google-earth-visual-guide>
- Remote Sensing Tutorial
<http://rst.gsfc.nasa.gov/Front/tofc.html>
- Federation of American Scientists
<http://www.fas.org/irp/imint>

Questions...

Badge...

<http://blogs.zdnet.com/Ou/?p=653>

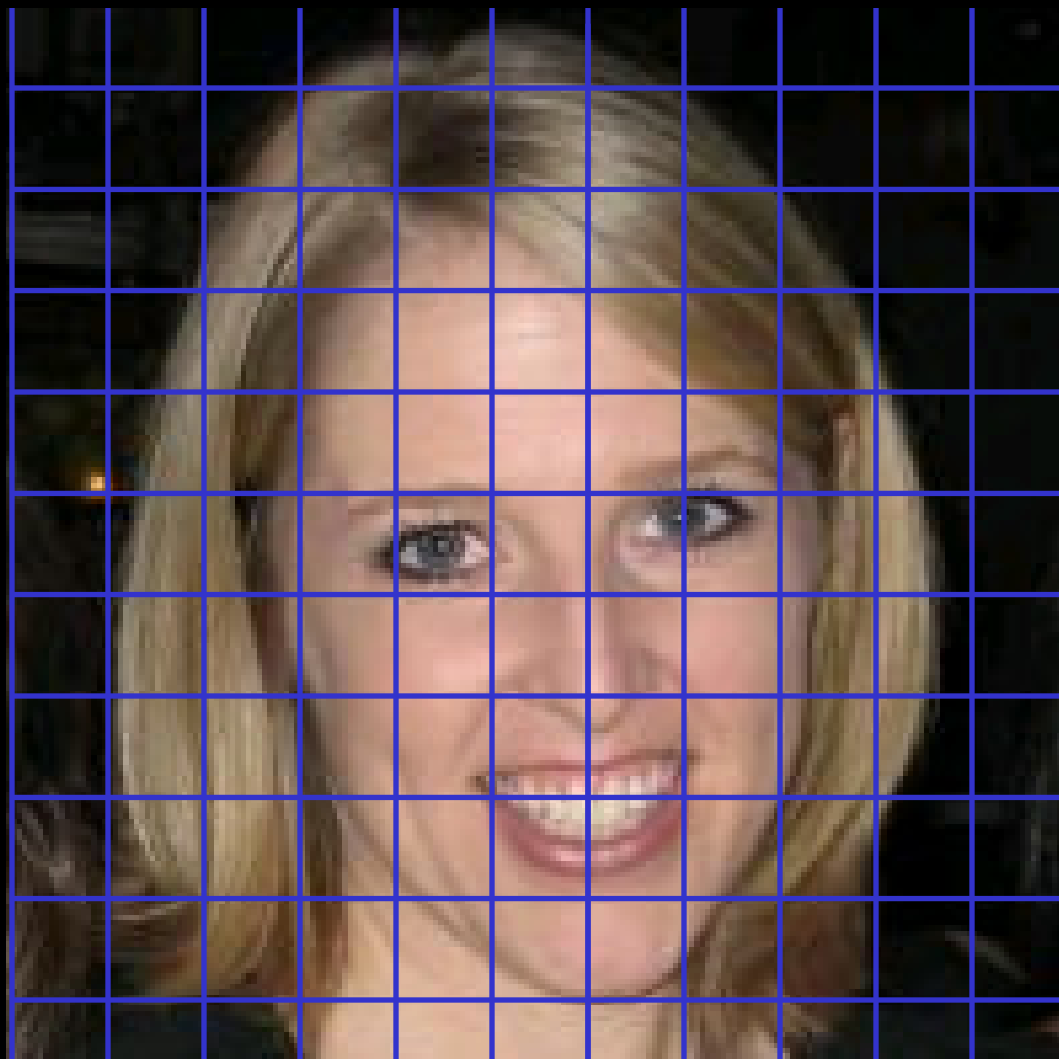
A satellite image of Earth from space, showing the eastern coast of South America and the Atlantic Ocean. The image is curved, showing the horizon of the planet. The land is green and brown, and the ocean is dark blue. White clouds are visible over the ocean and parts of the land.

Satellite Imagery Analysis

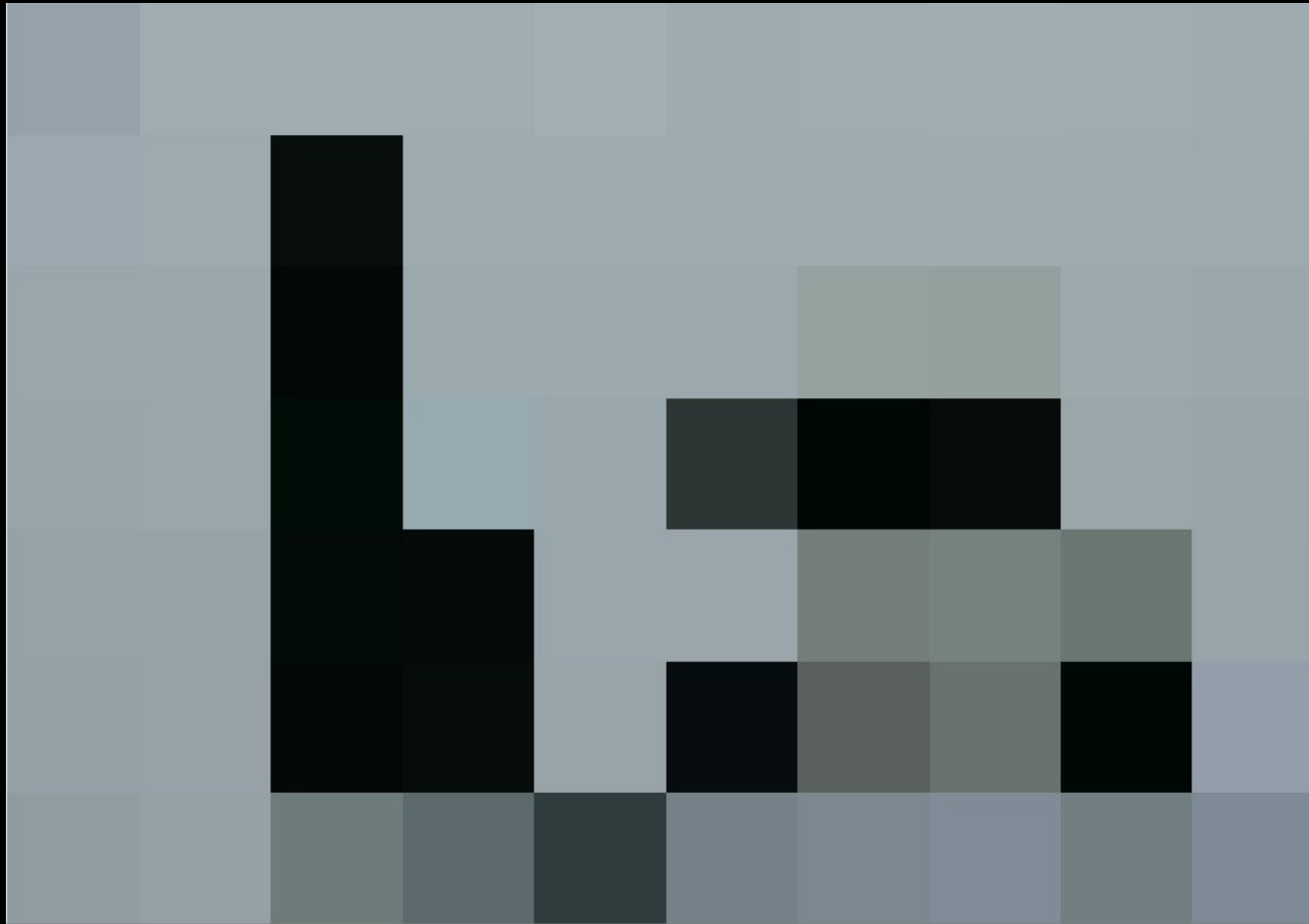
Greg Conti
gjconti@rumint.org

Sampling Example Slides

Step 1 – Sampling



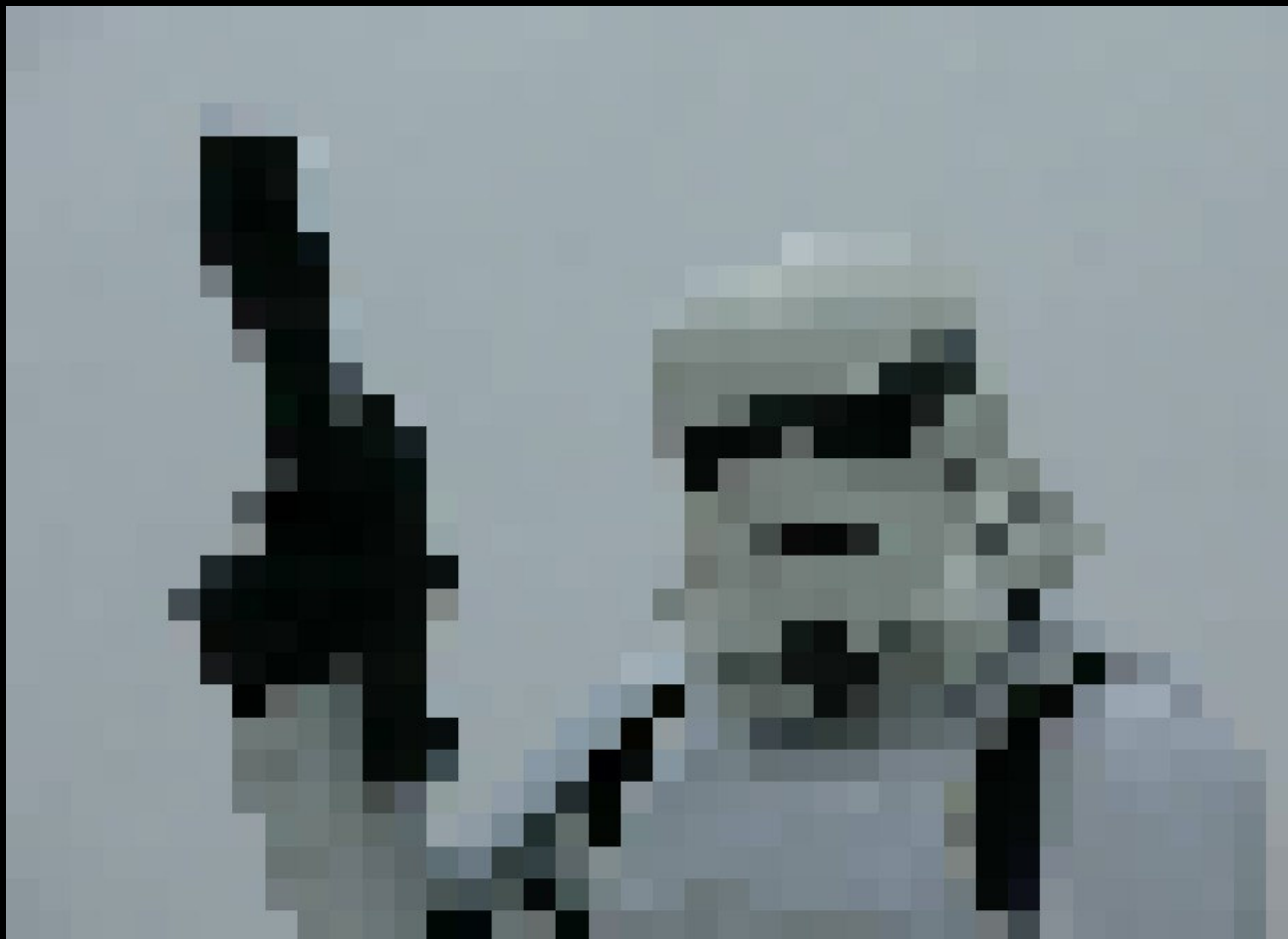
Step 1 – Sampling (7 x 10)



Step 1 – Sampling (14 x 20)



Step 1 – Sampling (29 x 40)



Step 1 – Sampling (59 x 80)



Step 1 – Sampling (119 x 160)



Step 1 – Sampling (239 x 320)



Step 1 – Sampling (487 x 638)



Step 2 – Quantization



1 Bit

Possible Colors: 2

Actual Colors: 2

Size: 26,100 bytes

Step 2 – Quantization



4 Bits

Possible Colors: 16

Actual Colors: 16

Size: 104,400 bytes

Step 2 – Quantization



8 Bits

Possible Colors: 256

Actual Colors: 256

Size: 208,800 bytes

Step 2 – Quantization



24 Bits

Possible Colors: 16,777,216

Actual Colors: 98943

Size: 626,400 bytes

Digitization

Digitization (also called Analog to Digital Conversion):
The **sampling** of an analog signal followed by **quantization** of the samples to finite numbers. A two step process. So:

Steps: **Digitization = Sampling + Quantization**

- 1. Sample reality** – convert an image into pixels a fixed distance apart, take the amplitude of a sound wave at discrete time intervals, etc.
- 2. Quantization** – take a set of continuous values and map them into a finite number of discrete steps represented by finite numbers.

Image Digitization

- **Spatial Sampling** – Measuring a continuously varying image at uniformly separated points in space and assigning a value that corresponds to an average light intensity within a small box surrounding each point.
- **Spatial Sampling Rate** – The number of samples of an image taken per unit of physical length of that image.
- **Bits per Pixel** – determines how many different colors could be represented by each pixel.