Virginia Tech Manufacturing Resources
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**Vertical Machining**

Haas VF-3 Machining Center

**Features & Specifications**
- 20,000 cubic inch machining space
- 8100 RPM
- Max cutting rate 650 in/min
- 20 station carousel tool changer
- Max tool diameter and weight 3.5 in. and 12 lbs

**Description and Benefits**
Haas VF-3 allows for complex milling operations in a contained environment. With multiple axes and 20 station tool carousel, complex parts can be created in a single cycle. The chip conveyor allows for mass production of parts. For these reasons the Haas VF-3 is ideal to produce complex machined parts on a large scale.
Features & Specifications

- Dovetail ways on the column, X table, and Y saddle for precision alignment
- Spindle Lock to easily change tools
- 6 spindle speeds from 130 to 2000 RPM at 60 HZ and 105 to 1670 RPM at 50 HZ
- Max movement area of 62.5 x 42 in.

Description and Benefits

CNC Baron offers an efficient and compact mill that is easy to learn and operate. It contains many features normally found in larger more expensive machines. It is ideal for both single parts or mass production.
Horizontal Machining
JET GHB-1340A Geared Head Lathe

Features & Specifications
- 8 spindle speeds from 70 to 2000 RPM
- 35 in carriage travel
- Spindle actuation control is apron mounted
- Compound and cross slide have backlash elimination

Description and Benefits
Variable speed and precision control allow the JET GHB-1340A to be a strong tool in calculated machining. It is currently being converted to be CNC capable, giving it the ability to be remotely controlled and making it an important tool in the development of cloud manufacturing.
Horizontal Machining
Ecoca PC-4615E PC-based Lathe

Features & Specifications
• One piece cast base for maximum stiffness
• Synchronized spindle for high speed threading
• Manual mode electronic hand wheels for X and Z axes combined with joystick feed and rapid motion control

Description and Benefits
A PC based lathe allows for high precision and control. It can be equipped for the acquisition of high density data.
Injection Molding
Babyplast Micro Injection Molding Machine

Features & Specifications
• Manages and stores up to 100 product cycles
• All movements are hydraulically controlled
• Low cost molds

Description and Benefits
Micro injection molding is ideal for creating small and microscopic parts from injectable thermoplastic materials. The uniform heating, hydraulic control, and low power consumption make it ideal for prototyping. Its small size and low noise output make it less cumbersome than other injection molding machines. Small plastic parts produced with the Babyplast are ideal for the medical, electrical, and consumer appliance industries.
PolyJet 3D Material Printing
Objet350 Connex 3D Printer

Features & Specifications
- X-Y Resolution of 600 x 600 dpi (42 micron in each direction)
- Layer thickness of 16 micron (high quality mode) or 30 micron (high speed mode)
- Multiple-material printing (stiff white material, flexible black material, and gradient mixtures between the two)
- Build volume of 350 x 350 x 200 mm
- Accuracy of 0.1-0.3mm

Description and Benefits
PolyJet 3D printing is similar to inkjet document printing. But instead of jetting drops of ink onto paper, PolyJet 3D printers jet layers of liquid photopolymer onto a build tray and cure them with UV light. The layers build up one at a time to create a 3D model or prototype. Fully cured models can be handled and used immediately, without additional post-curing. Along with the selected model materials, the 3D printer also jets a gel-like support material specially designed to uphold overhangs and complicated geometries. It is removed by hand and with water.

PolyJet 3D printing technology has many advantages for rapid prototyping, including superior quality and speed, high precision, and a very wide variety of materials. Based on PolyJet technology, Objet Connex 3D Printers from Stratasys are the only additive manufacturing systems that can combine different 3D printing materials within the same 3D printed model, in the same print job. The system offers more than 100 materials and digital material combinations to choose from, including rigid to rubber-like, opaque to transparent and materials with ABS-simulating performance.
PolyJet 3D Material Printing
MicroFab Technologies PH-04a Polymer Jet Inkjet Test Stand

Features & Specifications

- High-temperature drop-on-demand print head.
- JetDrive™ III controller, including command set and stand-alone control program. Includes built in strobe delay for drop analysis.
- Operation up to 240°C
- 60 µm orifice diameter
- 30 mL stainless steel reservoir
- Integrated, high-capacity, 10µm stainless steel filter.

Description and Benefits

This MicroFab inkjet test stand is used to analyze the jettability of novel polymers for Additive Manufacturing contexts. This capability enables researchers to evaluate and fine tune novel ink systems on a controlled platform prior to introducing them to 3D Printing equipment.

The PH-04a Polymer Jet™ high-temperature, drop-on demand printhead is designed for dispensing polymers and other materials at elevated temperature. Materials that must be heated above 50°C in order to melt and/or lower the viscosity of the fluid to less than 20cp can be dispensed using the PH-04a Polymer Jet™ printhead. Adhesives, optical polymers for light guides and lenses, and optically active materials have all been jetted successfully with the PH-04a.

The unit includes JetDrive™ III drive electronics, which is designed to provide complex drive waveforms to MicroFab’s MJ microdispensing devices. In addition, Aphelion image analysis software, with built in strobe control, enables video capture of individual droplets for ink analysis.
Fused Deposition Modeling (FDM)
Stratasys Dimension SST

Features & Specifications
• Layer thickness: 0.010 inch (0.254 mm) or 0.013 inch (0.330 mm)
• Max Build Size: 8 x 8 x 12 inch (203 x 203 x 305 mm)
• Materials: ABS polymer and water-soluble support material

Description and Benefits
The Stratasys Dimension SST system uses a fused deposition modeling (FDM) technology, which creates artifacts by selectively extruding a plastic filament. The Dimension SST works with an ABS polymer and a water-soluble support material.

Using an ABS polymer with the FDM technology has many advantages:
• Strong parts (Tensile strength of ABS is 5,000 psi)
• FDM ABS is machineable, sandable, and paintable
• Can be treated with resins to strengthen the plastic and increase heat resistance
• Relatively cheap compared to other AM processes (~$250.00 per 56 in³ of material)

In addition to the Dimension SST printer, there is supporting equipment including a water-base bath that is used to automatically remove the support material.
Fused Deposition Modeling (FDM)  
FDM 1500 & 1600

Features & Specifications
- Build area: 10.0x10.0x9.4 inches (250x250x240 mm)
- Accuracy +- 0.005 in 0.127mm
- Width 0.010 -0.100 inches (0.25 -2.54mm)
- Thickness 0.002-0.030 inches (0.05-0.76mm)
- Extrusion rate: 0.8 inches per second (20 mm/s) (ABS)
- Materials: ABS Plastic, Wax

Description and Benefits
The FDM 1500 & 1600 are early-model Fused Deposition Modeling machines. These machines feature the ability to build parts using ABS plastic and utilize a second nozzle to extrude support material. In addition to printing ABS these machines also offer the option of being configured to use investment casting wax as the extruded material.

Contrary to the more modern versions of this technology, these machines are able to be completely configured for research purposes. Researchers have the ability to process novel material systems and to explore a variety of process settings. In addition, the researchers have created in-house control software that enables direct control of the extrusion process without the need for a .STL file or using the built-in process planning software.
Fused Deposition Modeling (FDM)
Stratasys Uprint Plus

Description and Benefits
The Uprint Plus provides a compact and easy to use solution to 3D printing. It is easily installed and functional with Windows. It is ideal for prototyping and producing simple plastic parts.

Features & Specifications
- Max build volume 384 cubic inches
- No special facility requirements
- Layer thickness 0.01 in.
- Compact size
Fused Deposition Modeling (FDM)
Makerbot Replicator 2X

Description and Benefits
This is a very popular machine with DIY enthusiasts, retailing for under $3000. It is capable of plug-and-play compatibility with popular OS (both Windows and Mac). The dual nozzle allows multi-color printing without stopping the print. Heated bed allows more uniform build texture. A large “maker” community contributes to ease of troubleshooting.

Applications
Studying additive manufacturing processes, test-bed for developing novel process monitoring concepts in additive manufacturing, building custom parts for CMP experiments, education and training.

Features & Specifications
• Dual nozzle, heated bed.
• Build Volume 9.8” x 6.3” x 5.9”
• Three different layer resolutions (100 to 300 micrometers)
• X-Y positioning accuracy: 11 micrometers, Z positioning accuracy: 2.5 micrometers
• Filament dia: 1.75 mm
• Nozzle diameter: 0.4 mm
• 1.8° step angle with 1/16 micro-stepping
• 100—240V, 4 amps, 50—60 Hz
Projection Stereolithography

Features & Specifications
• Maximum emission: 0.8 mW/cm² at 365 nm
• Cross sectional build area: 67.7 mm x 50.8 mm
• Minimum feature size: 100 µm
• Minimum layer thickness: 8 µm

Description and Benefits
This projection stereolithography machine was developed within the DREAMS Lab to selectively cure layers of photopolymer resin loaded with nanoparticles such as quantum dots and carbon nanotubes.

This machine filters a broad spectrum light source to cure photopolymers reactive to 365nm light. However, changing the filter allows this machine to cure a variety of commercial and custom photopolymers reactive across the UVA and visible spectrums. And unlike commercially available machines, the hardware and operating software of this process can be completely customized for more specialized applications and research.

Because parts are peeled away from the resin vat, less excess photopolymer is required to submerge the build part. In addition, the unique recoating mechanism dramatically increases machine throughput.
Mask Projection Microstereolithography

Features & Specifications

- Maximum emission: 6.5 mW/cm² at 365 nm
- Maximum Build Volume: 11 mm x 6 mm x 40 mm
- Minimum feature size: <50 µm
- Minimum layer thickness: 25 µm

Description and Benefits

This mask projection microstereolithography system was developed in-house to cure layers of biocompatible photopolymer resin in order to fabricate microscale 3D objects. This system is expected to achieve feature sizes less than 50 µm.

A collimated UV LED light source, a 1080p Digital Micromirror Device (DMD), and supporting optics work together to selectively cure photopolymers responsive to 365nm light. As the machine was designed and built within the DREAMS Lab, researchers have complete control over the system parameters, to cure various photopolymers for any number of applications.
Selective Laser Sintering
DTM Sinterstation 2500 plus

Description and Benefits
Selective laser sintering (SLS) is one of the first and most advanced commercialized additive manufacturing (AM) technologies. The working material of SLS is micron-scale nylon powders. Additives are sometimes used to achieve desired mechanical properties (i.e. strength, flexibility, and temperature resistance). Layer by layer, a scans the desired pattern in the powder fusing the particles together and to the previous layer. A recoating roller spreads a uniform layer of powder 100 microns thick after each sintered layer.

Excluding metal-based additive manufacturing technologies, SLS produces some of the strongest AM components with relatively high resolution. Because it relies on a powder bed, there is no need for additional support material. The unsintered powder serves to support any overhanging structures during the build and is easily removed during post processing.

Virginia Tech’s two Sinterstation machines are ideal tools for creating functional and complex components directly from CAD models with favorable strength characteristics.

Features & Specifications
- Layer thickness: 4 mils (100 μm)
- Laser spot size: 15 mils (380 μm)
- Build Volume: 13” x 11” x 16.5”
- Build Speed: 0.5” to 1” per hour
Selective Laser Sintering
DTM Sinterstation 2000

Features & Specifications
- Max build volume 480 cubic inches
- 0.03 in resolution in the X/Y plane
- Minimum supported standing feature thickness 0.04 in
- Minimum unsupported standing feature thickness 0.08 in

Description and Benefits
The DTM Sinterstation 2000 creates artifacts by selectively sintering portions of a powder bed using a carbon dioxide laser. It primarily works with nylon polymer powder, but can also work with polymer-coated metal powder and a proprietary elastomer. Final products are typically very strong with very detailed features. The powder bed support structure removes the need to created additional support structures that are removed after production. This also allows for a simple post-processing of simply cleaning away excess powder from the part. Lastly, excess powder can be reused.

The machine allows for very complex geometries to be created. While it has its original uses in prototyping, it can be used for limited run end-use parts.
Description and Benefits
The ExOne R2 system is a binder jetting Additive Manufacturing technology, which creates metal artifacts by printing a binder into a bed of metal powder.

Speed of the Build: Much like a typical inkjet printer, the nozzles on the 3D printer can deposit many droplets of binder at one time. Therefore, each layer of the parts is “printed” much more quickly than other processes that use a laser or deposit material in only one place at a time.

Powder Bed Provides Support Structure: Unlike non-powder-based processes, 3DP uses the powder that surrounds the part to support overhanging features instead of having to build and later remove support structure.

Detailed Features: Very detailed features can be created because the precision of the printhead.

Material flexibility: Almost any powdered material can be processed using this technique. The DREAMS Lab has successfully processed polymers, metals, and ceramics.
3D Binder Printing
Z Corporation Spectrum Z™510

Features & Specifications
• Layer Thickness 0.0035-0.008 in.
• Build Speed 2 layers per minute
• Build Size 10 in. x 14 in. x 8 in.
• Resolution 600 x 540 dpi
• Number of Print Heads - 4
• Material Options: High performance composite, elastomeric, direct casting

Description and Benefits
The Spectrum Z510 Full Color System produces high-definition, full-color prototypes quickly and affordably. Superior inkjet printing technology creates parts with crisply defined features, enhanced accuracy, and precise color, so you can print and evaluate physical models of design concepts in their nearly finished state.

Direct Casting Metal Material creates sand-casting molds for metals. This material is a blend of foundry sand, plaster, and other additives that when combined produce strong molds with good surface finishes. Direct casting metal material can withstand the heat required to cast metals. Users of this “ZCast®” process can create prototype castings without incurring the costs and lead-time delays of tooling.
**Sintering**

MTI Tube Furnace EQ-GSL-1700X single zone series

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### Features & Specifications

- **Heating element:** Super 1800°C MoSi2
- **Dimensions:** 590mm×490mm×760mm (W x L x H)
- **Tube size:** 4” alumina tube
- **Power supply:** AC 208-240 V, 50/60 Hz 5KW
- **50 segments heating and cooling steps with +/- 1 Celsius degree accuracy.**
- **Compatible with a two-gas flow mixer**

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**Description and Benefits**

Furnaces are used for post-processing (e.g. sintering and reducing) of metal green parts manufactured by 3D printing systems.

EQ-GSL-1700X single-zone series furnace uses high-power electric molybdenum disilicide (MoSi2) heating elements, which can achieve faster heating and cooling rate. Stainless steel vacuum flange with valve, vacuum gauge and high purity ceramic tube are included for immediate use.

The furnace is connected with a gas mixing system. This configuration allows to heat samples in vacuum or flowing gas. Multi-stage sintering cycles are easily programmed and automatically executed via computer control.
3D Scanning
FARO ScanArm V3

Features & Specifications
- Accuracy ± .0014 in.
- Scan rate up to 19,200 points/sec
- Non-contact measurement
- Exact scanning of reflective and dark objects

Description and Benefits
Non-contact measurement devices are becoming more and more popular. Handheld laser scanners provide a quick and effective way to inspect and reverse engineer complex parts and surfaces. They turn everyday objects into digital computer models. Soft, deformable, and complex shapes can be easily inspected — all without ever coming in contact with the part.

The FARO ScanArm combines all of the advantages of the FaroArm with a hand held laser scanner and is the perfect contact/non-contact measurement system. Unlike other scanning systems, the ScanArm’s hard probe and the Laser Line Probe can digitize interchangeably without having to remove either component. Users can accurately measure prismatic features with the hard probe, then laser scan sections requiring larger volumes of data — all in one simple tool.

The FARO ScanArm is the ideal tool for inspection, point cloud-to-CAD comparison, rapid prototyping, reverse engineering, and 3D modeling.
3D Scanning
Handyscan EXAscan 3D scanner

Features & Specifications
- Weight 2.75 lbs.
- Accuracy ± .0016 in.
- Scan rate up to 25,000 measures/sec
- Non-contact measurement
- Eye-safe laser system

Description and Benefits
The Handyscan 3D scanner is a data acquisition system and its own positioning system. This means that no external tracking or positioning devices is required. It uses triangulation to determine its relative position to the part in real time. The scanner can be calibrated as often as necessary (day-to-day basis or before each new scanning session). Calibration takes about 2 minutes and guarantees optimal operation.

The EXAscan offers increased accuracy and resolution. It is the most versatile 3D scanner on the market for inspection and demanding reverse engineering. The direct .stl files generated can easily be imported into inspection software and quickly processed. The EXAscan can help you with the scanning and measuring of objects of any sizes in various environments, generating inspection and colorimetric reports.
Real Time 3D Scanning
MayScanner 1312 Precision 3D Scanning System

Features & Specifications
• Number of 3D pixels/point cloud: 300K ~ 18 Mega.
• Accuracy: Sub micron ~ mm (1/10,000 ~ 1/60,000 of the dimension of the object).
• Speed of 3D data construction: 1 sec ~ 20 ms
• Real-time scanning: 10 ~120 3D/s.
• Object dimension: sub cube inch ~ cube meters.
• Standoff: 20 mm ~ 3 meters (adjustable).

Description and Benefits
Advantages: The most promising feature of this scanner is its high speed for 2D/3D scanning as well as 3D point cloud data construction, with high reconstruction accuracy. This enables in-situ online process monitoring for many applications such as 3D printing. The stability of the dual vision structure is very reliable. The multi fringe structure lighting and the dual eye visual structure makes the system suitable for scanning wide variety of objects with different color or intensity, different materials under different ambient light environment. Non-contact optical measurement will not damage the object to be scanned.

Applications
Rapid prototyping and additive manufacturing; human 3D face, security, industry measurement, 3D sculpture cutting; product geometry dimension verification, quality control; CAD/CAE/CAM; medical research, clinical aiding, life science; plastic surgery; customized ear aiding devices.
# Infrared Temperature Measurement

## FLIR A615

**Features & Specifications**
- 640 x 480 pixel IR resolution
- 16-bit temperature linear output
- GigE Vision™ standard compatibility
- GenICam™ protocol support
- Digital inputs/outputs
- Windowing mode

## Description and Benefits

The FLIR A615 targets R&D and automation applications and is an instrument for industries which rely on permanent monitoring of objects that are fast moving or when the temperature changes over time is quiet fast. FLIR A615 infrared cameras also comply with standards like GigE Vision and GenICam. Due to its compliance to standards, the FLIR A615 infrared camera is a Plug&Play device within third parties' machine vision software like NIs IMAQ Vision™ and the MVTecs Halcon™. Examples of applications include PCB testing, validation and design verification within the automotive, medical and power electronics industries.
Visual Inspection
Mitutoyo Quick Image Microscope

Features & Specifications
• 1.16 x 0.87 in field view
• 0.87 in focal depth
• 1-4x digital zoom
• 11.8 x 6.7 in travel range

Description and Benefits
Quick Image is a color vision measuring instrument for easy and reliable non-contact precision measurement of small work pieces, surfaces, and contours. The strength of this compact table-top unit lies in its ability to measure difficult, complex, soft, and highly structured parts. The provided software allows for quick setup and viewing. For these reasons the Quick Image is a valuable tool for quality and part inspection.
Visual Inspection
OMAX 4X-100X Microscope

Features & Specifications
- High quality professional optical glass elements
- 45° inclined 360° swiveling binocular head
- Easy to mount electronic eyepiece (digital microscope camera)
- 4 levels of magnification: 4X-10X-40X-100X
- 4 achromatic objectives DIN 4X, 10X, 40X(S), 100X(S,Oil)
- 2 pairs of eyepieces: WF10X and WF20X
- Sliding interpupillary distance adjustment
- Ocular diopter adjustable on both eyetubes
- Variable intensity illumination

Description and Benefits
The OMAX 4X-100X Lab LED Binocular Compound Microscope allows to magnify items and specimens at multiple levels. This particular model provides the following levels of magnification: 4X-10X-40X-100X. For basic biological studies or more advanced chemistry projects, this microscope has covered many of the most common magnification levels to choose from. Users can easily choose to increase or decrease magnification levels.
Visual Inspection
Steindorff® S-620 Metallurgical Microscope

Description and Benefits
This trinocular microscope is specially designed for metallurgical analysis. Ideally suited to observe and identify the structure of various metals and alloys, it also can be widely used in electronics, chemical and instrumentation industry. It can be used to observe both opaque material and transparent materials, such as ceramics, integrated circuits, electronic chips, printed circuit boards, LCD panels, film, powder, toner, wire, fibers, plated coatings, and other non-metallic materials.

Applications
Surface and defect characterization on CMP polished surfaces, AM parts, part defect characterization. Can be used to capture still images, as well as, videos.

Features & Specifications
- Trinocular viewing head, inclined at 30°, interpupillary distance 48mm-75mm
- Extra wide field eyepiece EW10x/22mm
- Infinite achromatic objective, 7 magnification levels up to 100X
- Bright-field/Dark-field, with three filters: Blue, Green, Yellow.
- Double layer mechanical stage 186 x 138mm / 74mm x 50mm
- 1/2.5" 5.0MP CMOS Image Sensor (4:3)
Polishing
Buehler Ecomet/Automet 300 Automated MEMS Sensor Based CMP Polisher

Features & Specifications
• 12 inch platen size
• Bi-directional platen rotation from 50-400 RPM
• 60-150 RPM Head speed
• Fully automated work holding spindle, with feedback regulated load activation
• Dual mode, central and single force operation
• Integrated, high fidelity MEMS wireless sensor array with sustained sampling at > 750 Hz

Description and Benefits
Advantages: The most promising feature of this equipment is the ease of adaptability for polishing different types of substrates, e.g. silicon dioxide wafers, copper, ceramics, gem stones, etc. Multiple samples (up to 6), differing in size can be polished on this apparatus to nanometer level (Ra < 5 nm) surface finish. The work holding arrangements can be easily customized to accommodate patterned wafers up to 4 inches in diameter. The unit includes a specially built wireless MEMS sensor array, capable of sustained high fidelity sampling (> 750 Hz) for over 5 minutes. A variety of sensors can be mounted on the apparatus, ranging from vibration to temperature sensors.

Applications
Multi-stage Chemical Mechanical Planarization (CMP), sensor-based process quality monitoring, specular quality polishing.
Variation Analysis
3DCS Software

Description and Benefits
3DCS Variation Analysis (also known as tolerance analysis) is used to drive the design (both geometry and tolerances) to meet defined quality and cost requirements, while meeting component manufacturer’s capabilities.

Tolerance Analysis offers engineers the opportunity to optimize component tolerances and maximize quality while minimizing costs. The optimal time to complete the variation analysis model is as early in the product's lifecycle as possible such as to make the most impact to the overall design quality. Whether the quality characteristics are for fit, finish, aesthetic properties or functional requirements, 3DCS software technologies will improve the assembly quality.
Netfabb Selective Space Structures Software

**Description and Benefits**

Netfabb's Selective Space Structures is a unique piece of software that allows for the easy creation of highly detailed structural parts. By breaking down any solid CAD model into a series of small voxels, Selective Space Structures can then replace those tiny voxels with custom tailored unit cell structures. This unit cells can vary spatially within the part.

By replacing solid material with small cellular truss structures, it is possible to eliminate mass without sacrificing the strength of the part. However, it would be impossible to physically create these parts without the unique advantages offered by additive manufacturing.

In addition, the netfabb software is capable of directly manipulating STL files. This includes performing operations such as file/part repair, Boolean addition and subtraction, and mesh refinement.

**Features & Specifications**

- Software capable of populating any design with cellular structures
- Create lightweight, yet strong parts
- Custom designed unit cell structures based on trusses or any other STL shape
- Capable of handling unit cells of varying size or geometry within a single part
- Additional capabilities include STL repairs and Boolean operations
3D Visualization
VisCube Visionarium

Features & Specifications (stats for each wall and floor):

• Dimensions: 120”x120” (10ft square)
• HD Projectors: EPSON PowerLite Pro Cinema 9500UB with Infitec color shifting (4 per wall)
• Contrast Ratio: 200,000:1
• Brightness: 3200 lumens (before Infitec)
• Resolution: 1920×1920 per wall

Description and Benefits:

Displays:
Stereoscopic rendering with nearly full surround screens has proven benefits for the exploration, analysis and visualization of spatial information. Users can get immersed in complex models at human scale. With the brightness and pixel count of the VisCube, we are able to interactively render complex scientific and engineering data sets from CAD programs to Supercomputer simulations. Support for international data standards and open source software insure that visualizations can be portable, interoperable and durable.

Motion Tracking:
To really take the immersion to the next level, the VisCube uses an advanced, wireless Intersense motion tracking system. It tracks the 3D position and orientation of the primary user’s (the ‘driver’) glasses and of a hand-held controller, rendering the scene to their perspective. This allows them to literally walk around objects within their virtual world.

https://snoid.sv.vt.edu/visionarium/
http://www.youtube.com/user/VTVisionarium/