SoftWare for the Optimization of Radiation Detectors (SWORD)

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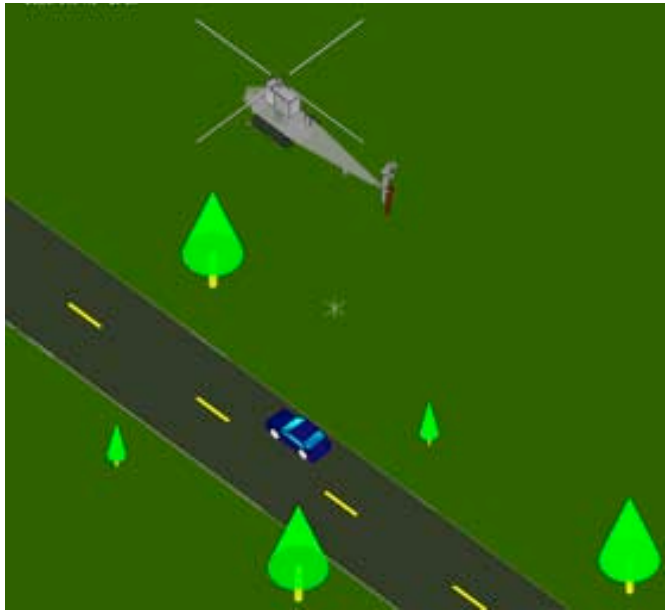
SRA

Physics-Based Modeling in Design & Development for U.S. Defense Conference

Outline

- Introduction to SWORD
  - Motivation
  - User Interface
  - Standard Library
  - Analysis tools
- SWORD Extensions in Progress
  - MCNPX/6 Adapters
  - ADVANTG Adapters
  - Conversion of GIS data into SWORD
  - Radiography tools
  - Backtrace (GEANT4)
- SWORD in Operational Use
- Conclusions



SWORD Motivation

- Simulation allows evaluating and optimizing performance before devoting resources to creating an instrument
- Typically, simulation has been an exercise for the expert user
- SWORD attempts to bring the power of simulation to everyday users

SWORD Motivation

- What it looks like in GEANT4 …

```
            particleName );

G4VPhysicalVolume const* pCurrentVolume = pTrack->GetVolume();
G4String currentVolumeName = pCurrentVolume->GetName();
TVolumeId currentVolumeId = gVolumeRepository->getVolumeId( convertFromString< size_t >( currentVolumeName ) );

track.setVolumeName( currentVolumeId.getName() );

const G4StepPoint*  g4PreStepPoint  = stepData->GetPreStepPoint();
const G4ThreeVector g4PreStepPos    = g4PreStepPoint->GetPosition();
TPoint preStepPoint( g4PreStepPos.getX()/cm, g4PreStepPos.getY()/cm, g4PreStepPos.getZ()/cm );
preStepPoint.setEnergy( g4PreStepPoint->GetKineticEnergy() / keV );
preStepPoint.setTime( g4PreStepPoint->GetGlobalTime()/s );
track.setPreStepPoint( preStepPoint );

const G4StepPoint*  g4PostStepPoint  = stepData->GetPostStepPoint();
const G4ThreeVector g4PostStepPos    = g4PostStepPoint->GetPosition();
TPoint postStepPoint( g4PostStepPos.getX()/cm, g4PostStepPos.getY()/cm, g4PostStepPos.getZ()/cm );
postStepPoint.setEnergy( g4PostStepPoint->GetKineticEnergy() / keV );
postStepPoint.setTime( g4PostStepPoint->GetGlobalTime()/s );
track.setPostStepPoint( postStepPoint );

uint64_t eventNumber = runManager.getCurrentEventNumber();
if( gDetectorRepository.isDetector( currentVolumeId ) ) {
    gEventRepository.saveEvent( eventNumber );
}

if( gEventRepository.loggingSupportedParticlesOnly() ) {
    if( gParticleNames.isSupported( particleName ) ) {
        if( gEventRepository.loggingDetectorHitsOnly() ) {
            if( gDetectorRepository.isDetector( currentVolumeId ) ) {
                gEventRepository.addTrack( eventNumber, track );
            } else {
                G4VPhysicalVolume const* pNextVolume = pTrack->GetNextVolume();
                if( pNextVolume != 0 ) {
                    G4String nextVolumeName = pCurrentVolume->GetName();
                    TVolumeId nextVolumeId = gVolumeRepository->getVolumeId( convertFromString< size_t >( nextVolumeName ) );
                    if( gDetectorRepository.isDetector( nextVolumeId ) ) {
                        gEventRepository.addTrack( eventNumber, track );
                    }
```

SWORD Motivation

- What it looks like in MCNPX/6 …

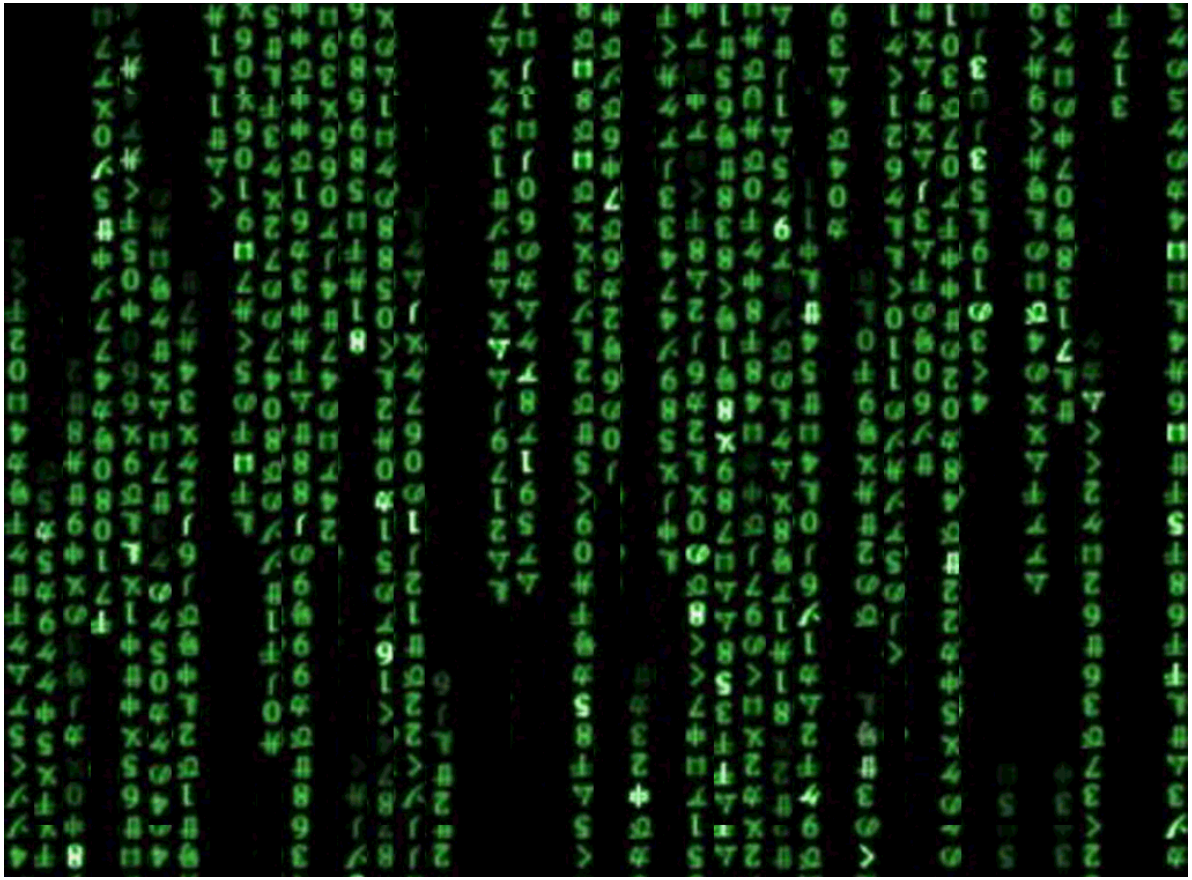
```
254   5   -0.00129 -254
      255 256 257 258 259
      260     IMP:N=1
261   5   -0.00129 -261
      262 263 264 265 266
      267     IMP:N=1
268   5   -0.00129 -268
      269 270 271 272 273
      274     IMP:N=1
275   5   -0.00129 -275
      276 277 278 279 280
      281     IMP:N=1
282   5   -0.00129 -282
      283 284 285 286 287
      288     IMP:N=1
253   5   -0.00129 -253 254 261 268 275 282    IMP:N=1
336   5   -0.00129 -336
      337 338 339 340 341
      342     IMP:N=1
343   5   -0.00129 -343
      344 345 346 347 348
      349     IMP:N=1
321   5   -0.00129 -321
      322 323 324 325 326
      327     IMP:N=1
328   5   -0.00129 -328
      329 330 331 332 333
      334     IMP:N=1
320   5   -0.00129 -320 321 328    IMP:N=1
335   5   -0.00129 -335 336 343    IMP:N=1
289   29   -0.9 -289     IMP:N=1
290   29   -0.9 -290     IMP:N=1
291   29   -0.9 -291     IMP:N=1
```

```
90   BOX   -401.295 69.75139999999999 105.2
      69.63 0 0
      0 181.1536 0
      0 0 0.1
91   BOX   -401.295 116 105.2
      69.63 0 0
      0 4 0
      0 0 0.1
98   BOX   -401.295 116 -105.3
      69.63 0 0
      0 4 0
      0 0 0.1
92   WED   -331.665 116 105.2
      -69.63 0 0
      0 -2 0
      0 0 0.1
99   WED   -331.665 116 -105.3
      -69.63 0 0
      0 -2 0
      0 0 0.1
93   BOX   -401.295 122 105.2
      69.63 0 0
      0 4 0
      0 0 0.1
100   BOX   -401.295 122 -105.3
      69.63 0 0
      0 4 0
      0 0 0.1
94   WED   -331.665 126 105.3
      -69.63 0 0
      0 2 0
      0 0 -0.1
101   WED   -331.665 126 -105.2
```

```
      25000   0.017097
      26000   0.69624
      28000   0.092256
      6000   0.0013801
m9   1000   0.65714
      6000   0.34286
m27   1000   0.0209
      13000   0.59362
      14000   0.12039
      29000   0.25203
      6000   0.013062
m29   1000   0.46392
      13000   0.058168
      6000   0.45692
      7000   0.0069995
      8000   0.013999
m15   13000   0.048808
      14000   0.18635
      20000   0.092439
      5010   0.010509
      5011   0.043108
      8000   0.61878
MODE p e n h d t s a #
PHYS:P 100 0 0 -1 0 0
PHYS:E 100 0 0 0 0 1 1 1 1 0
PHYS:N 100 100 0 -1 j 0 2
CUT:P 2j 0 0
CUT:E 2j 0 0
CUT:N 2j 0 0
print -85 -86
prdmp 2j 1 3
DBCN 28j 1
```

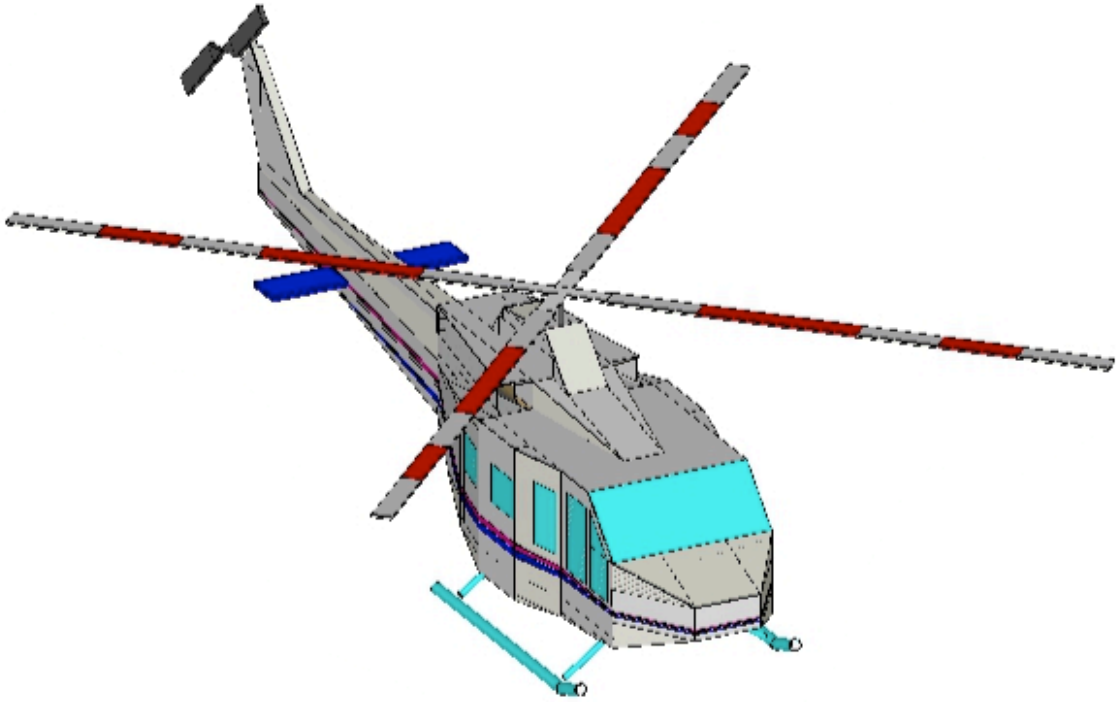
SWORD Motivation

- What it looks like to the new users …



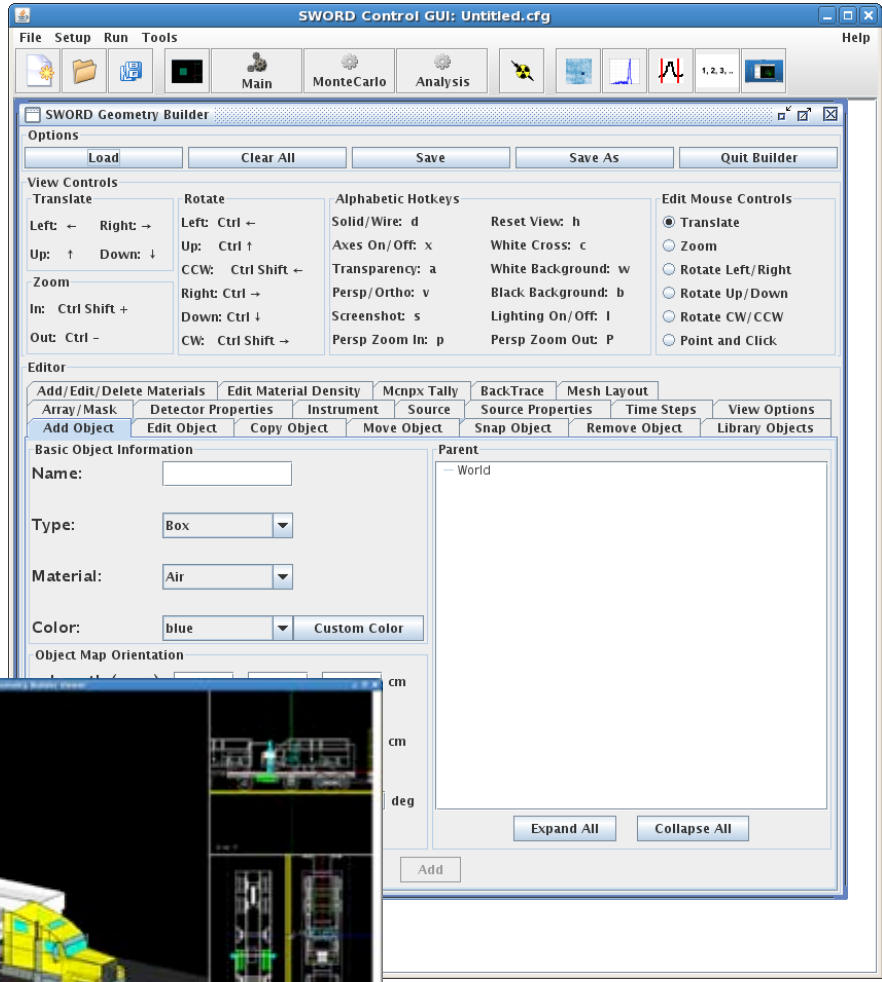
SWORD Motivation

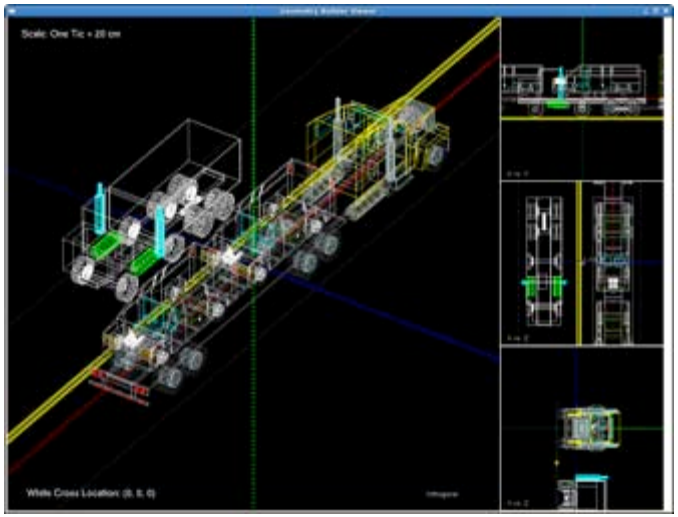
- What you'd really like is …



SWORD User Interface

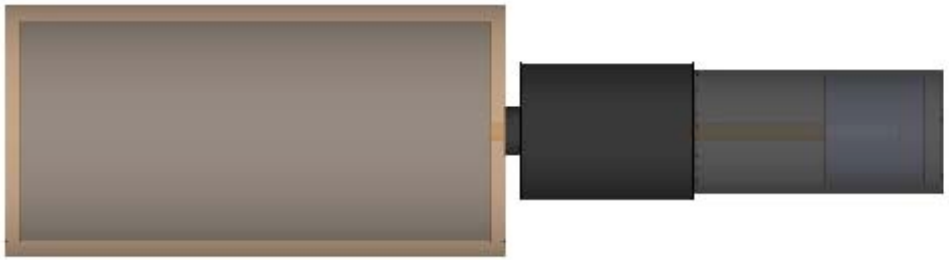
- Graphically set up geometries, sources, detectors
  - Main and Orthogonal Views
  - Wireframe and Solid Rendering
  - Eight primitive shapes
- User can define new materials not included with SWORD
- Add motion to objects



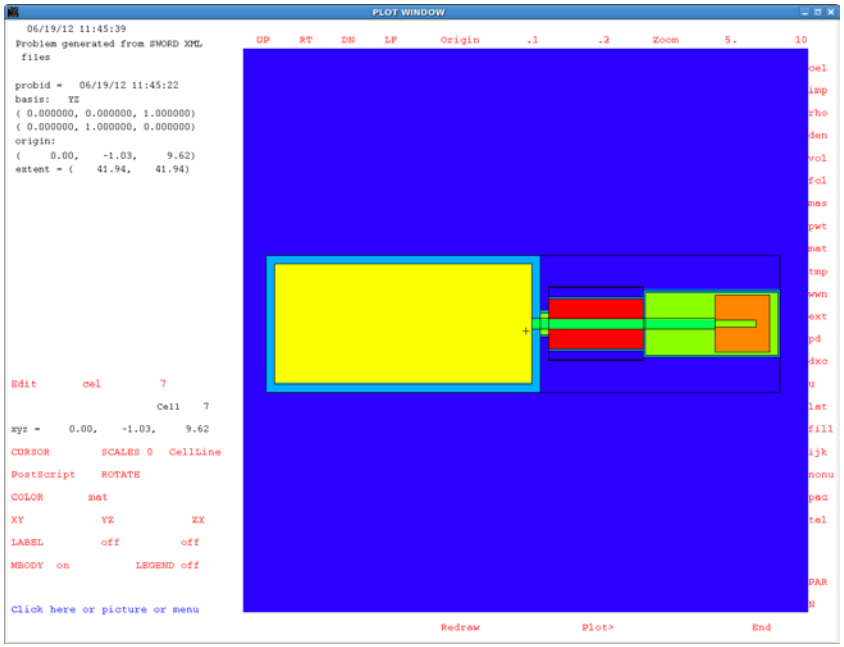


Multiple MC Engines

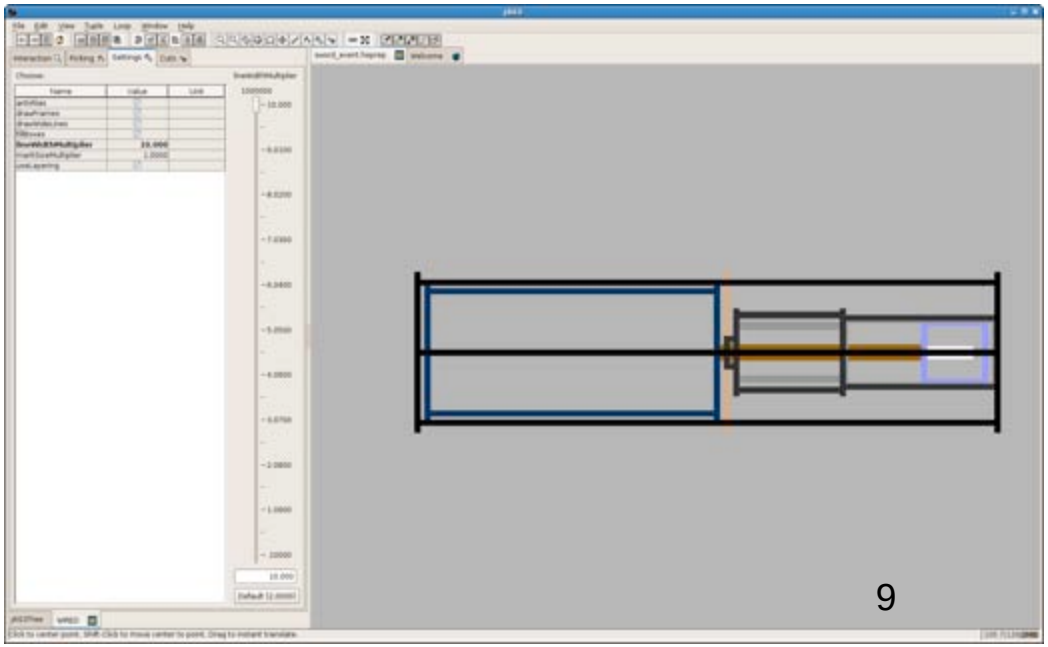
SWORD



MCNPX

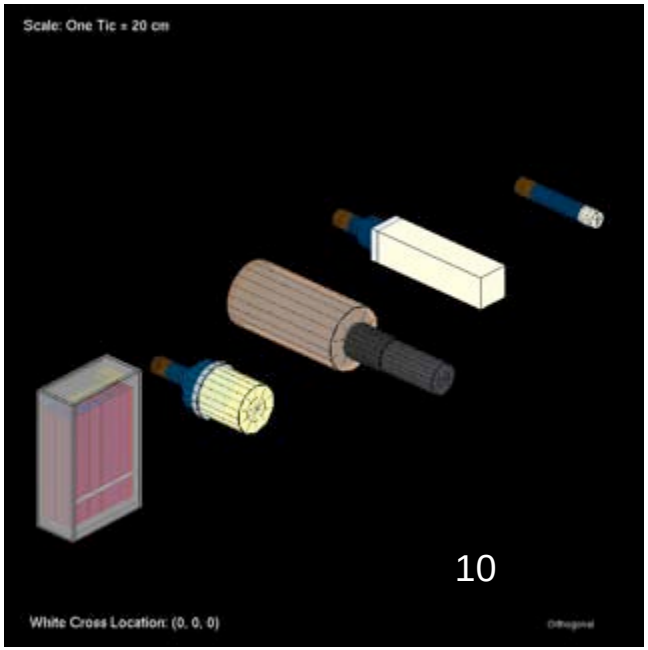


GEANT4



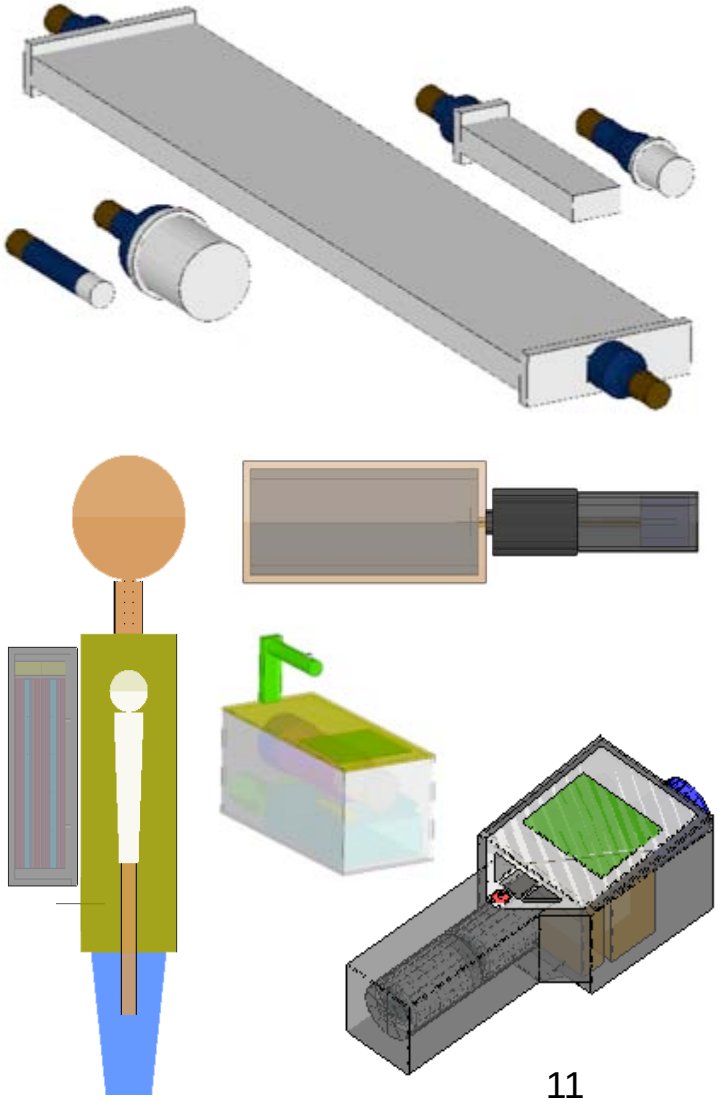
SWORD Standard Library

- Extensive standard library of objects for use in simulations
  - Detectors (neutron, gamma)
  - Vehicles (Land, Sea, Air)
  - Containers
  - Rail cars
  - Environmental Objects
  - Spectra
    - Threat objects
    - NORM backgrounds
    - Medical isotopes
- SWORD library is expandable
  - Objects can be imported into various projects
  - Spectra from sources or backgrounds of interest can be added



SWORD Standard Library
Commercial Detectors

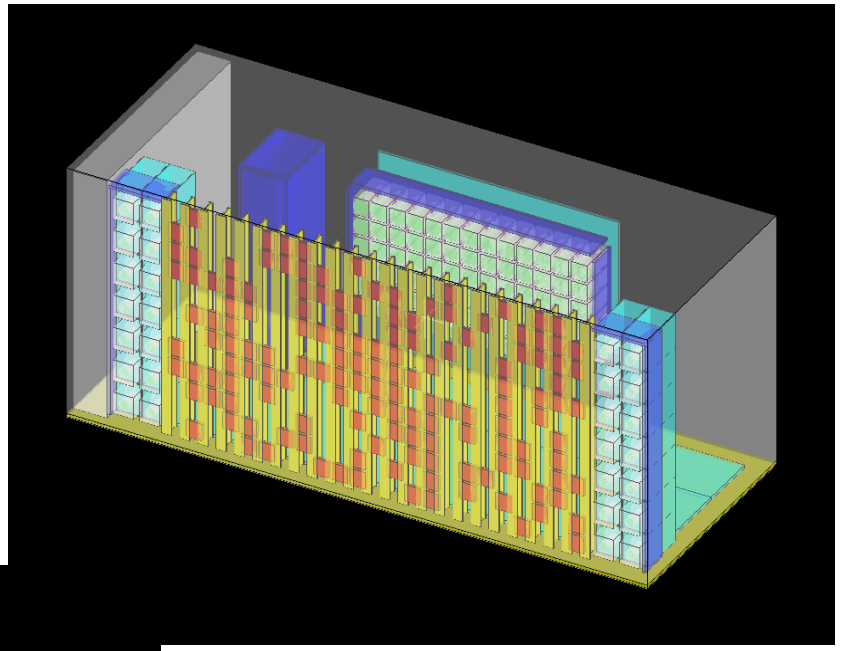
- Several COTS detectors
  - 3”, 6”, 4x2x16, 4x4x16 NaI
  - HPGe PopTop
  - identiFinder
  - GR-135+
  - RadPack
  - Plastic Scintillator
  - 2” CLYC

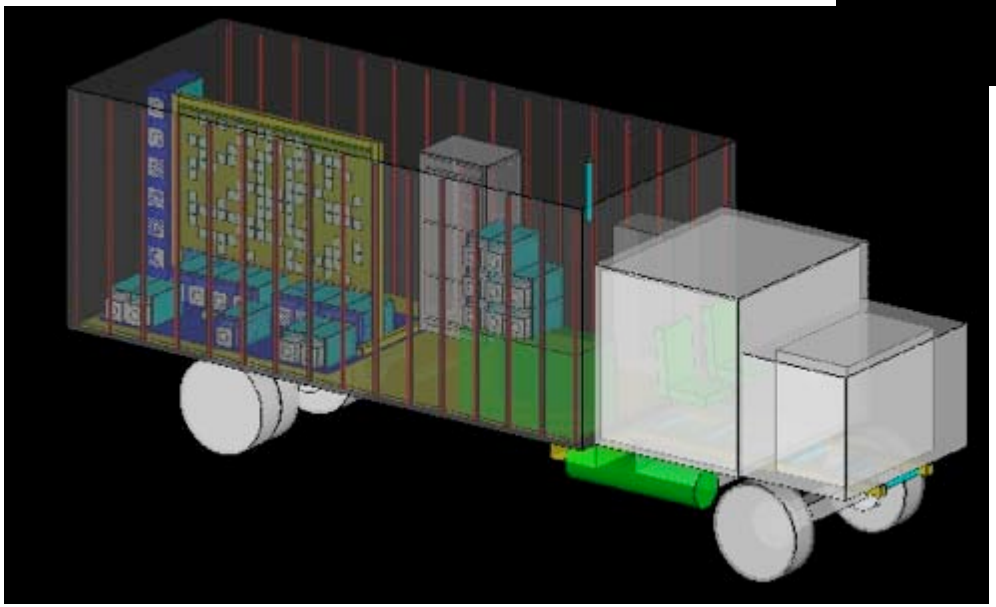


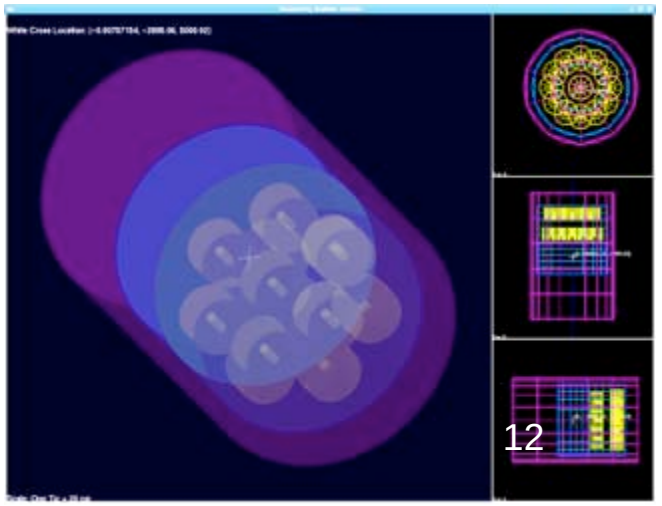
SWORD Standard Library

Specialized Detectors

- MISTI
- SuperMISTI
- MARS

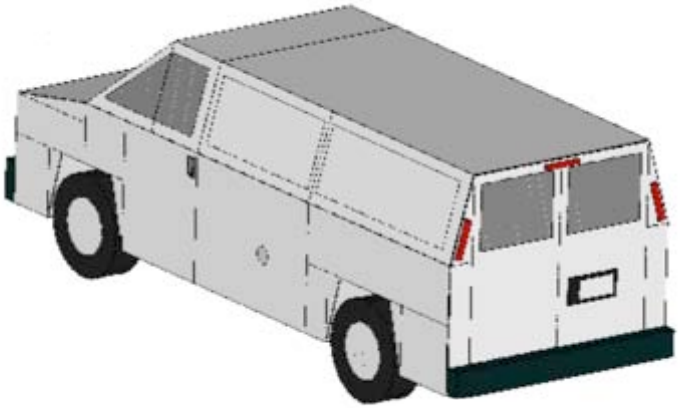


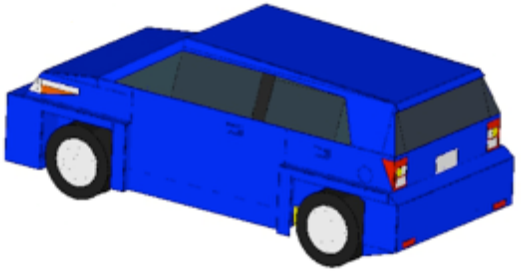


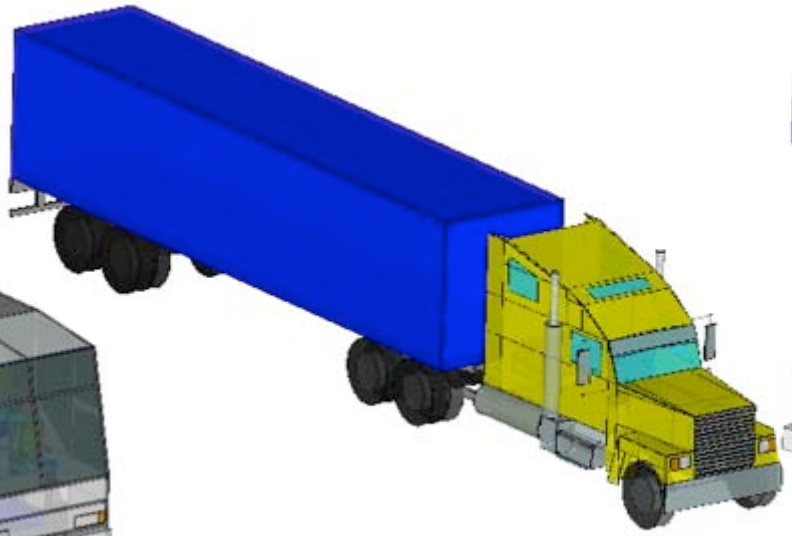


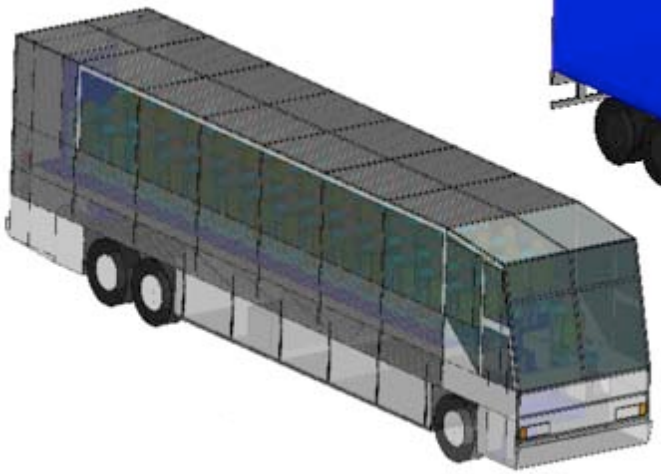
SWORD Standard Library
Land Vehicles

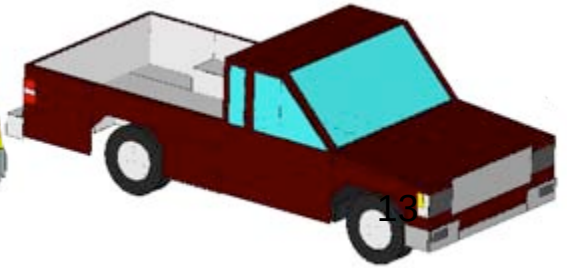
- Tour Bus
- Tractor Trailer
- Pickup Truck
- Compact Car
- Minivan





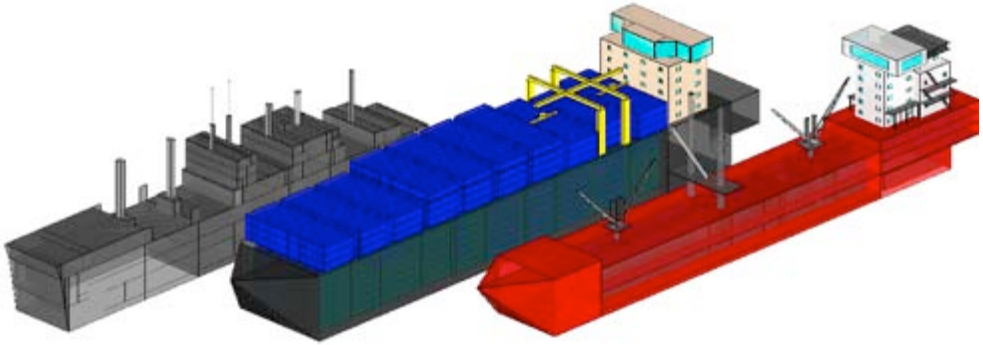




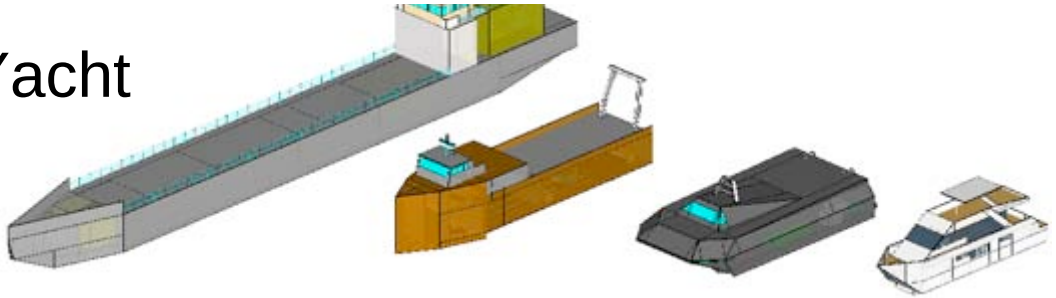


SWORD Standard Library
Ships

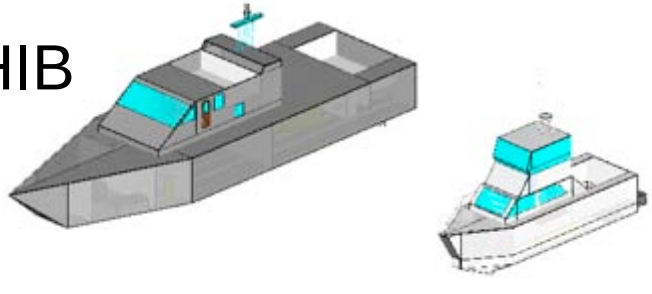
- Chalmers, Titus, Avatar



- Atlas, Diane-G, Stiletto, Yacht

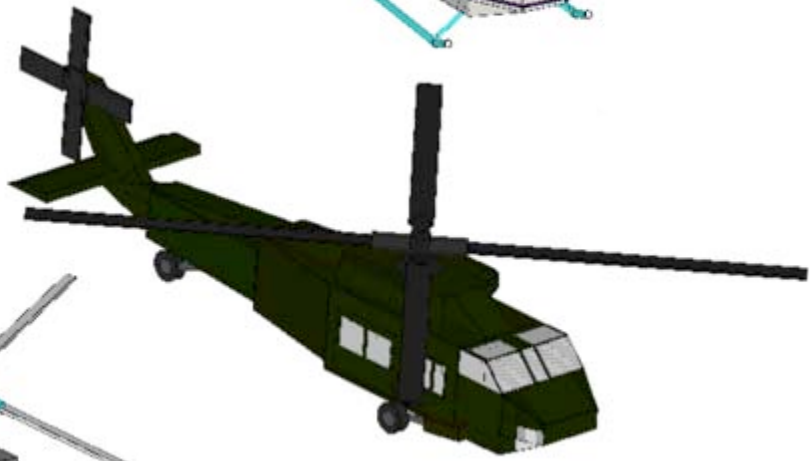


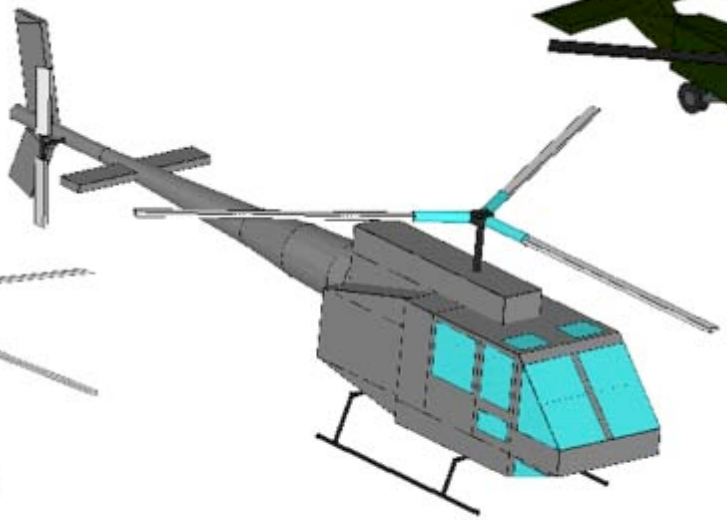
- Guardian, Pacific Venture, RHIB

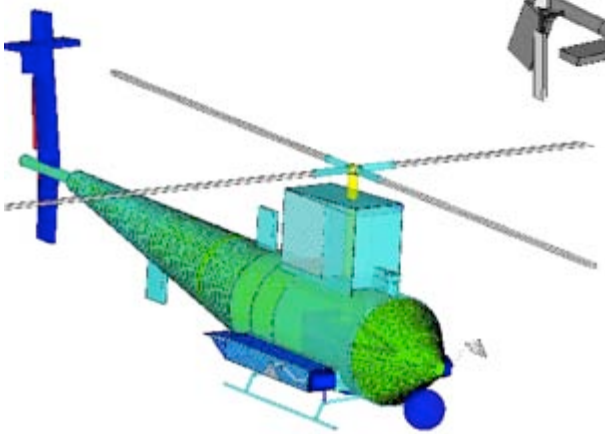


SWORD Standard Library
Helicopters

- Firescout UAV
- Eurocopter AS350 Ecureuil
- Blackhawk UH-60
- Bell 412

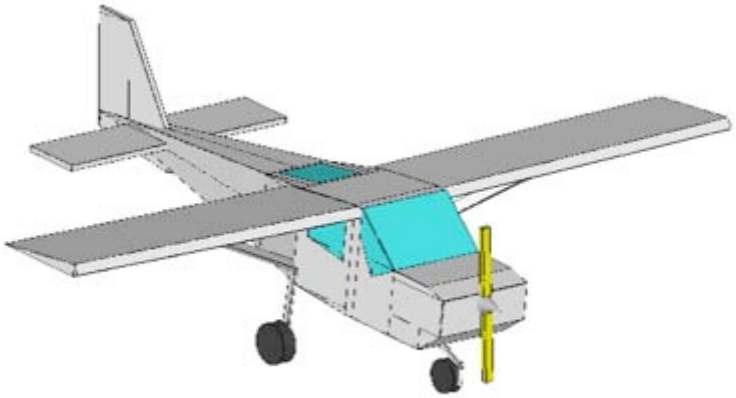


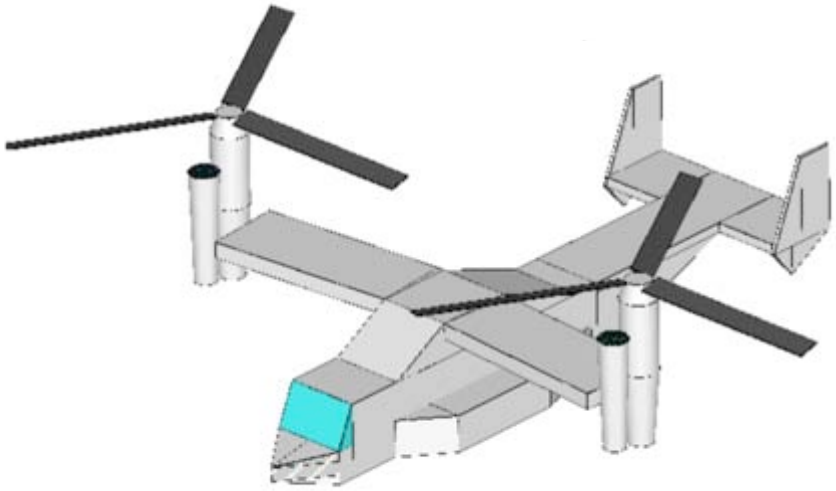


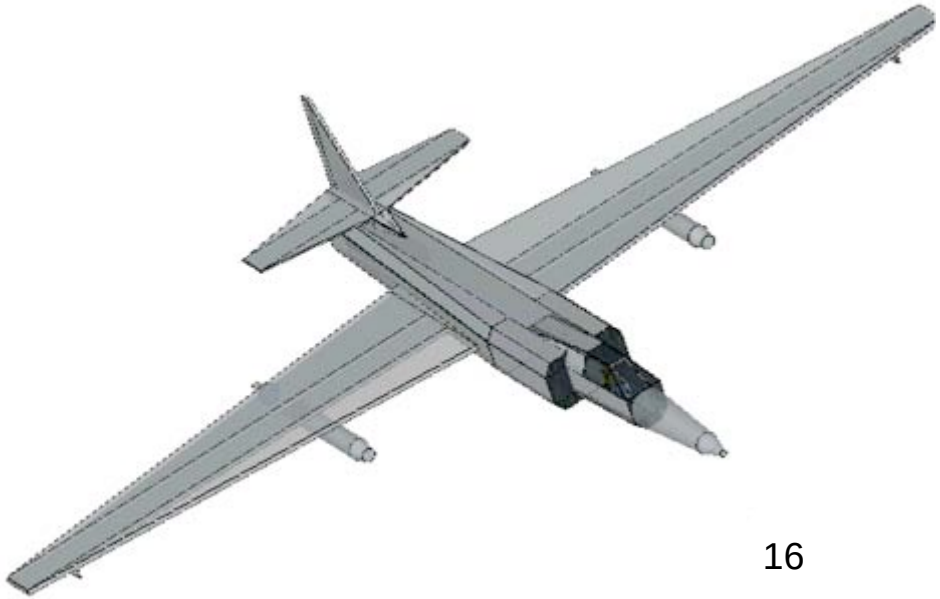


SWORD Standard Library
Aircraft

- Bell Boeing V-22 Osprey
- NASA ER-2
- Cessna Skycatcher



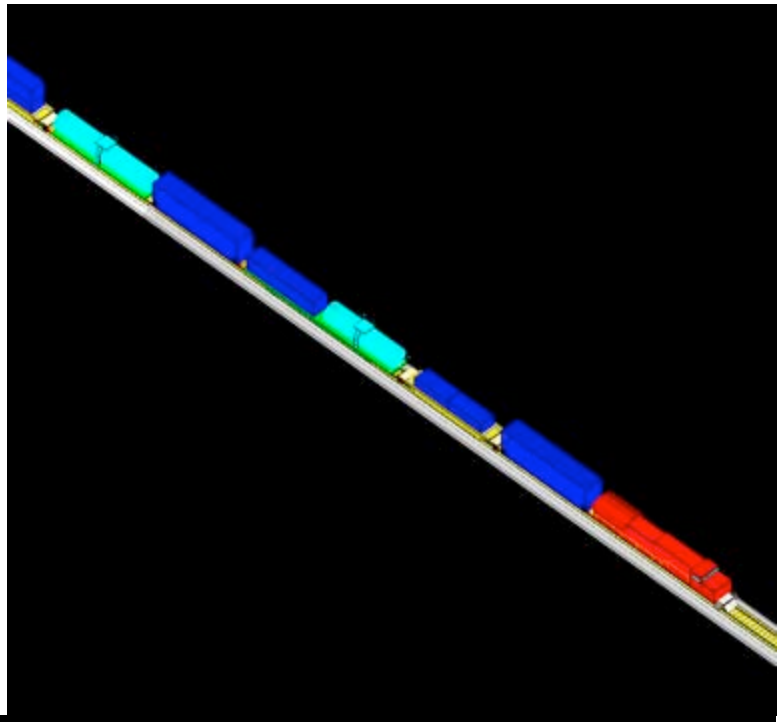


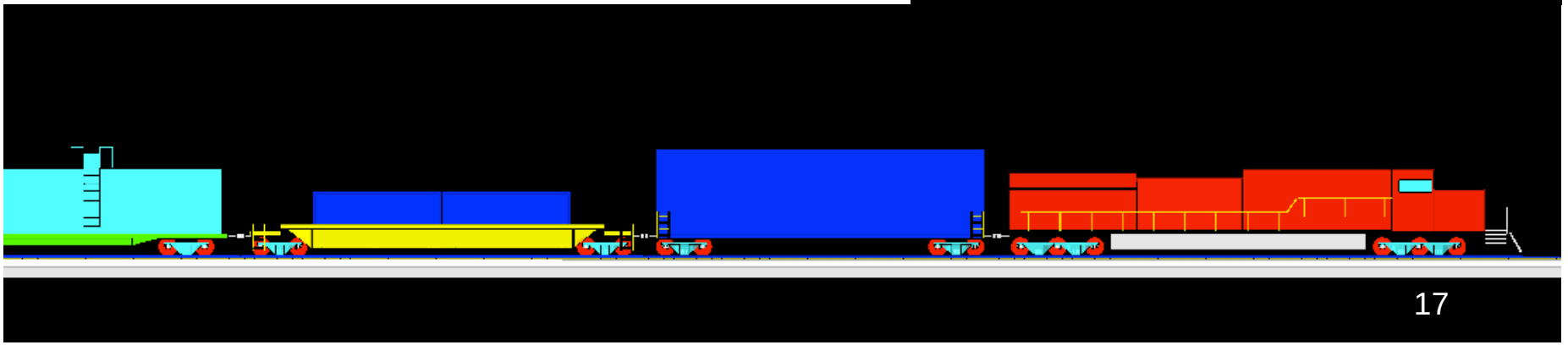


SWORD Standard Library

Rail

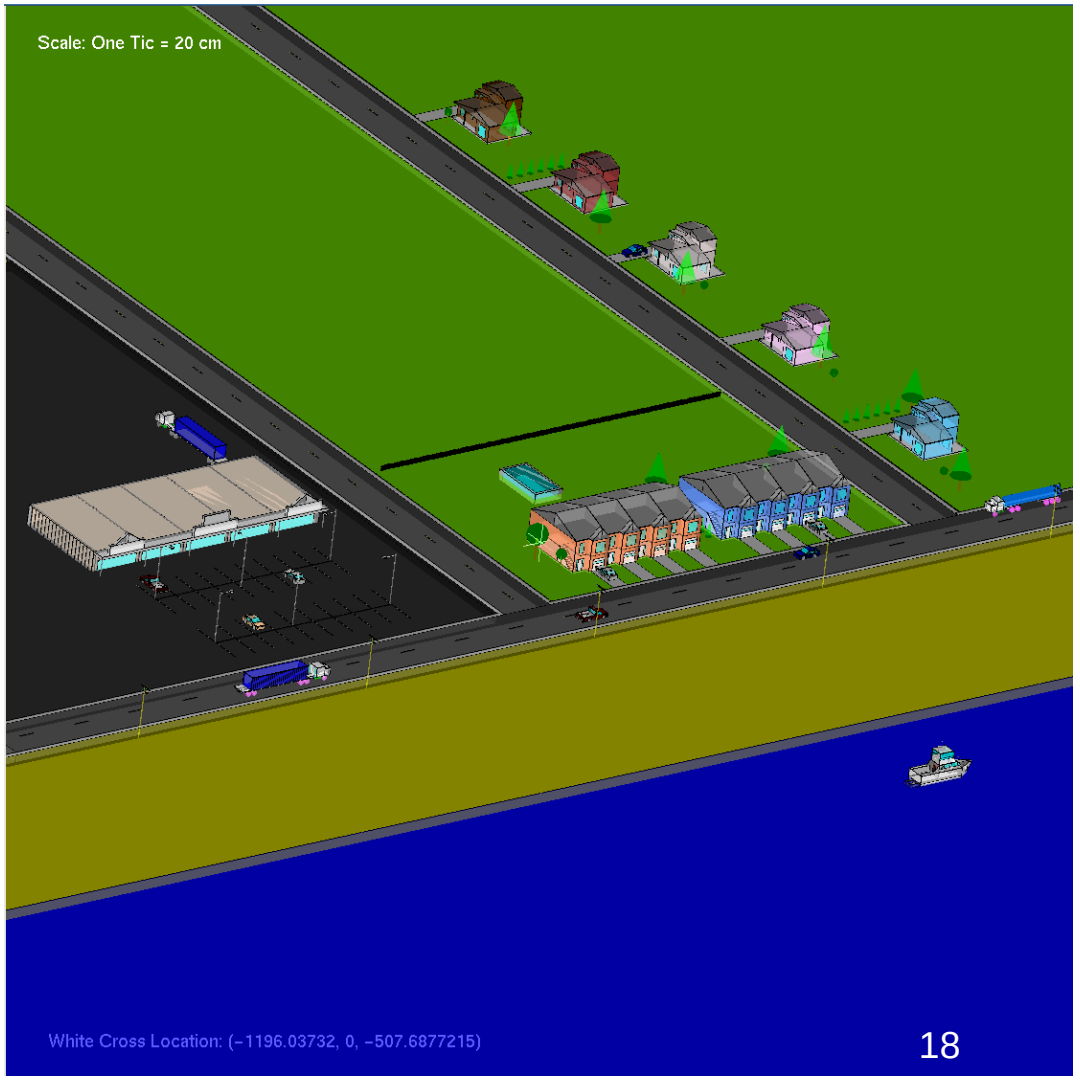
- Locomotive
- Box Car
- Well Car
- Gondola
- Tanker





SWORD Standard Library
Neighborhood

- Created entire neighborhoods
  - Townhouses
  - Strip Mall
  - Stand alone homes



Library of Background Sources

- Background simulation crucial for simulating instrument performance
- SWORD provides background spectra including
  - Concrete
  - Fresh water
  - Salt water
  - Common cargo found in shipping containers:
    - Fertilizer, limestone, cat litter, brazil nuts
- Developed mechanism for rapid deconvolution of new concrete spectrum given a measured spectrum

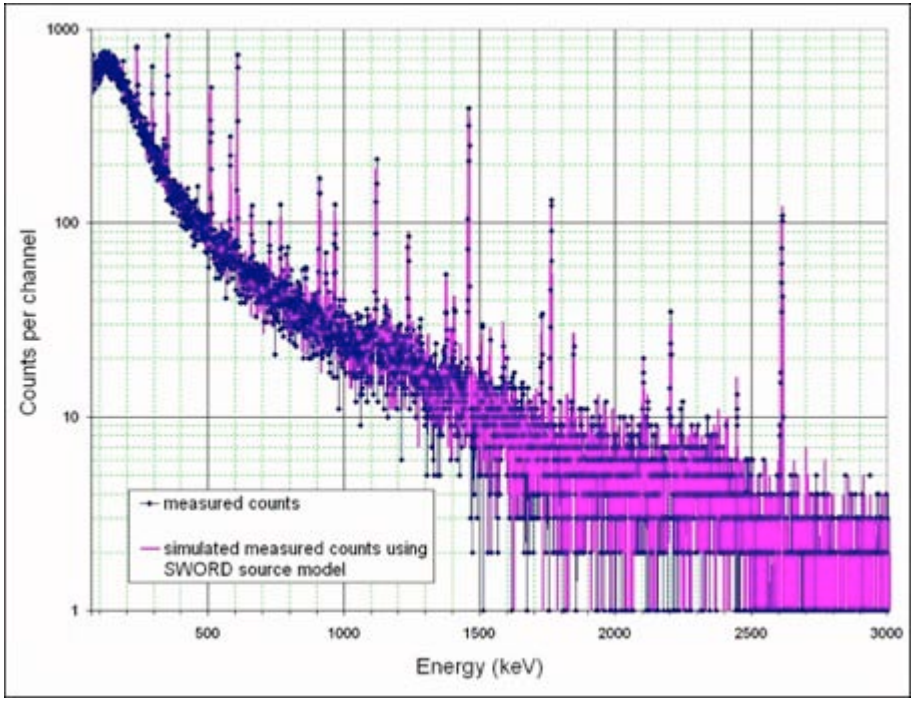
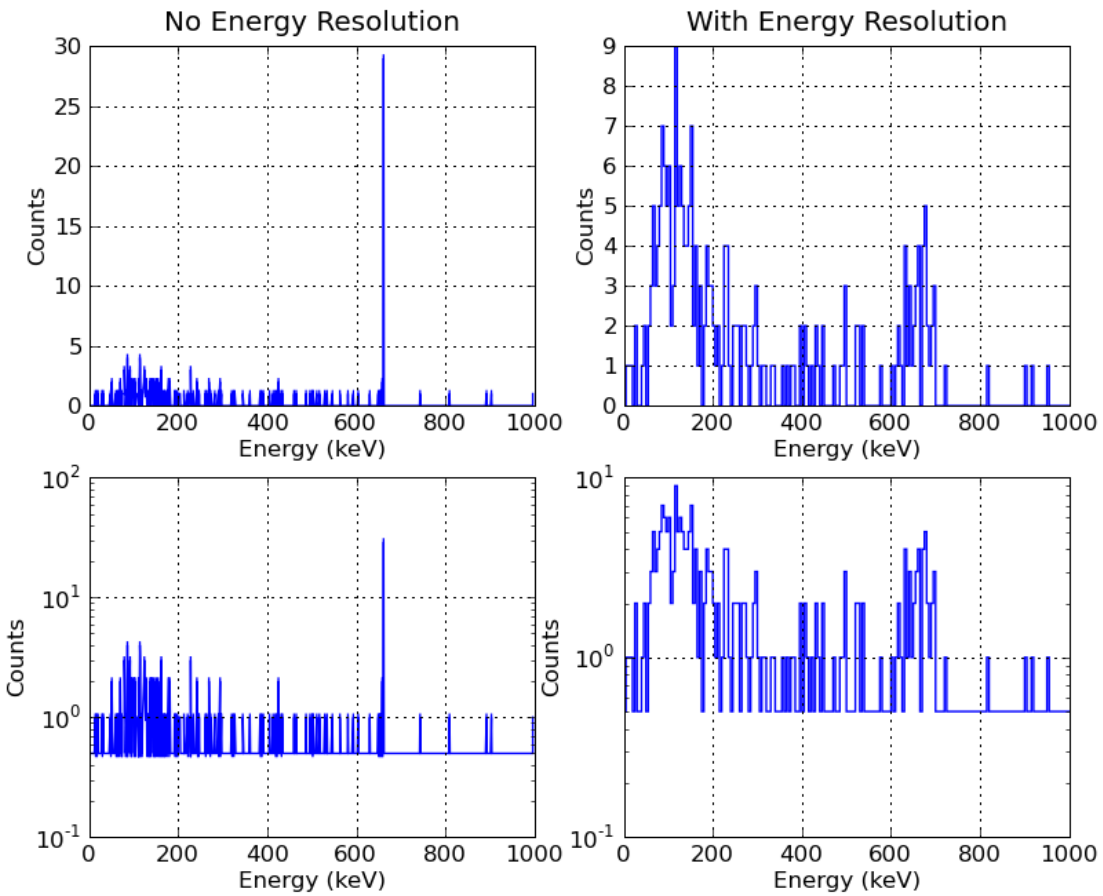


Figure: Simulated spectrum (magenta) vs. detected spectrum using HPGe (blue)

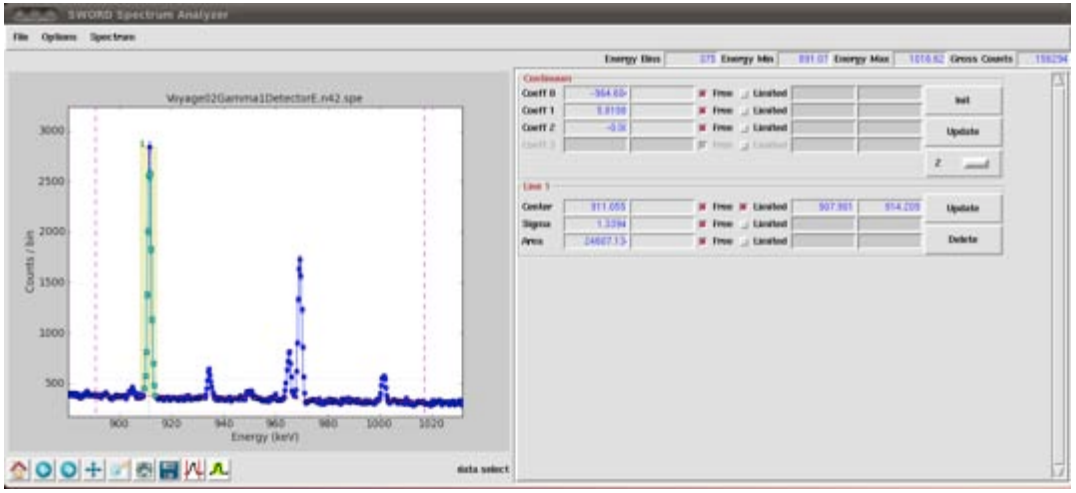
SWORD Analysis

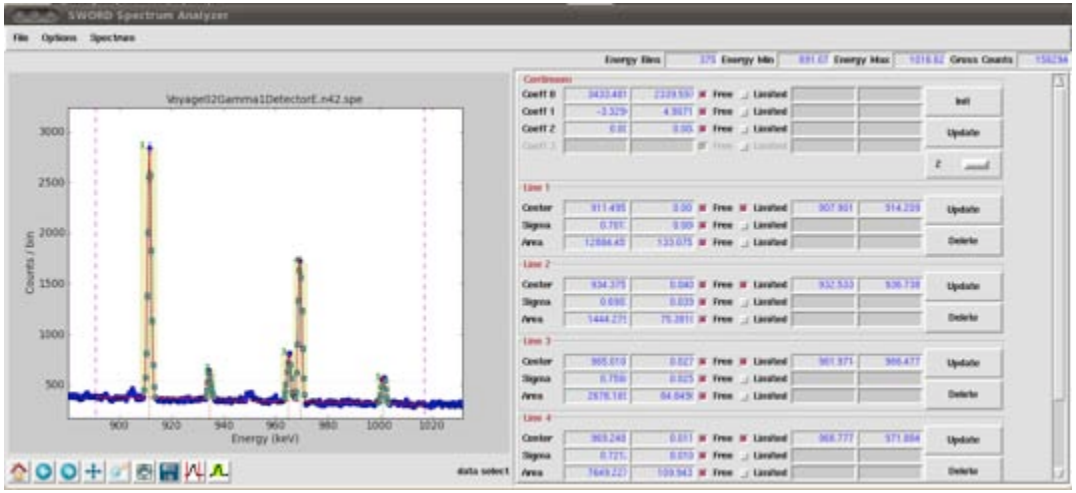
- Spectrum produced in ANSI 42.42 format
- Spectra displayed with and without detector response



SWORD Analysis

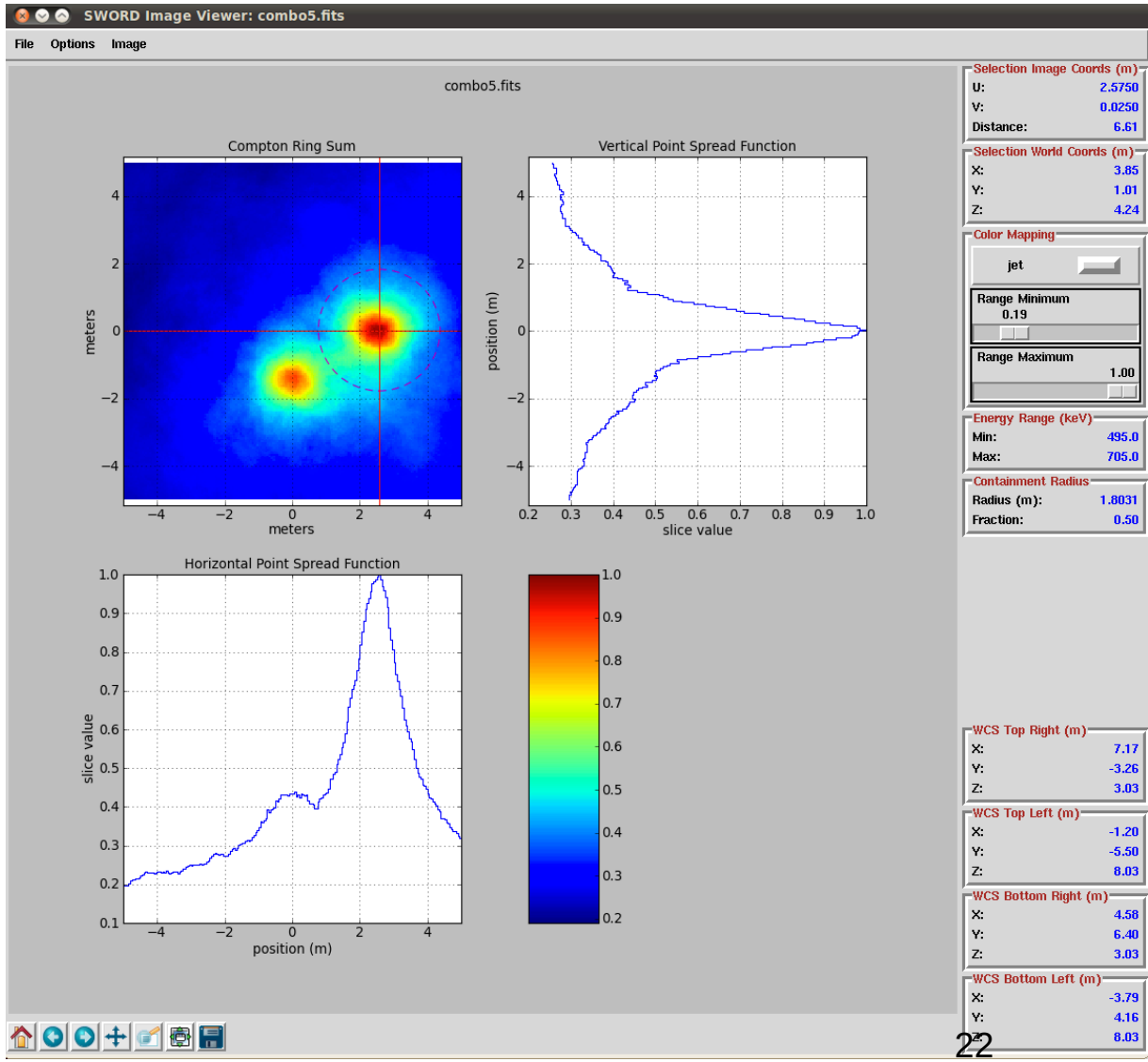
- SpectrumAnalyzer
  - Analyzes spectra from SWORD (or data in .spe or N42.42 format)
  - Line fitting using MPFIT
  - Isotopic line identification





SWORD Analysis

- Images produced in NASA FITS format
- Limited imaging performance analysis
- Can also use standard FITS tools such as SAOImage/DS9 or FV



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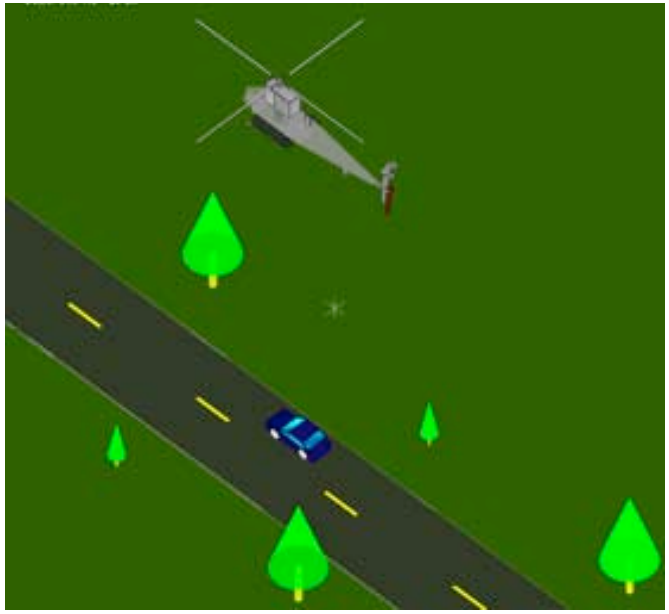
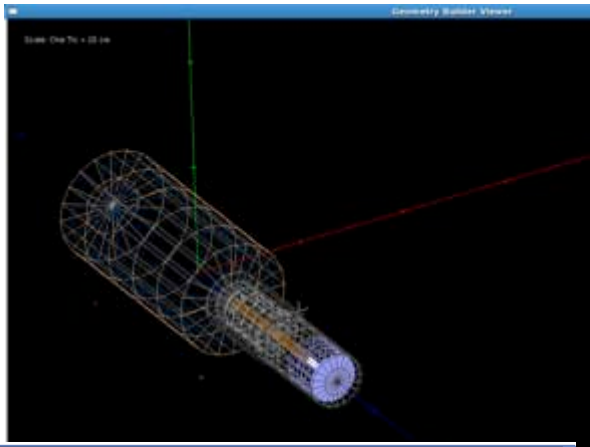
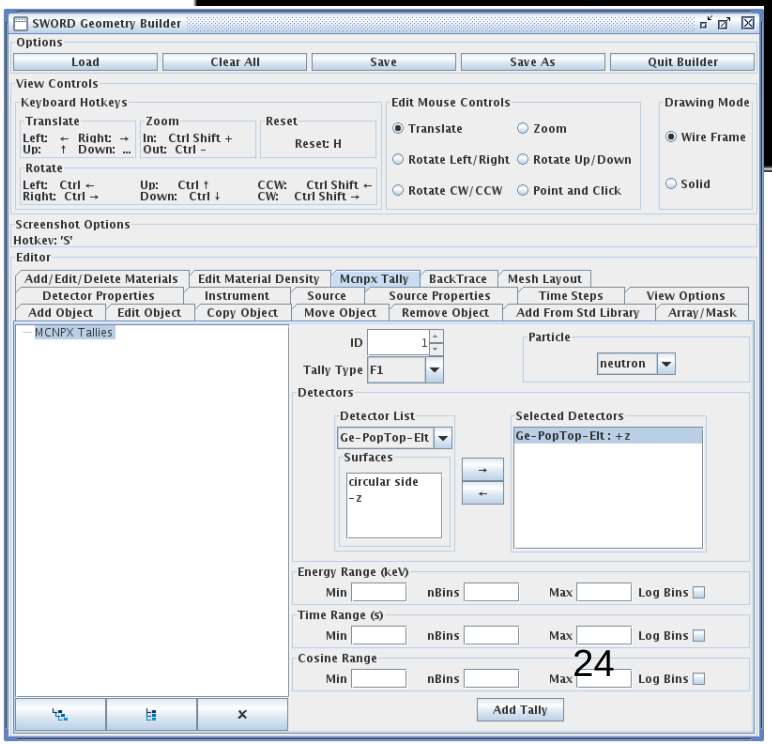


MCNPX/6 Adapters

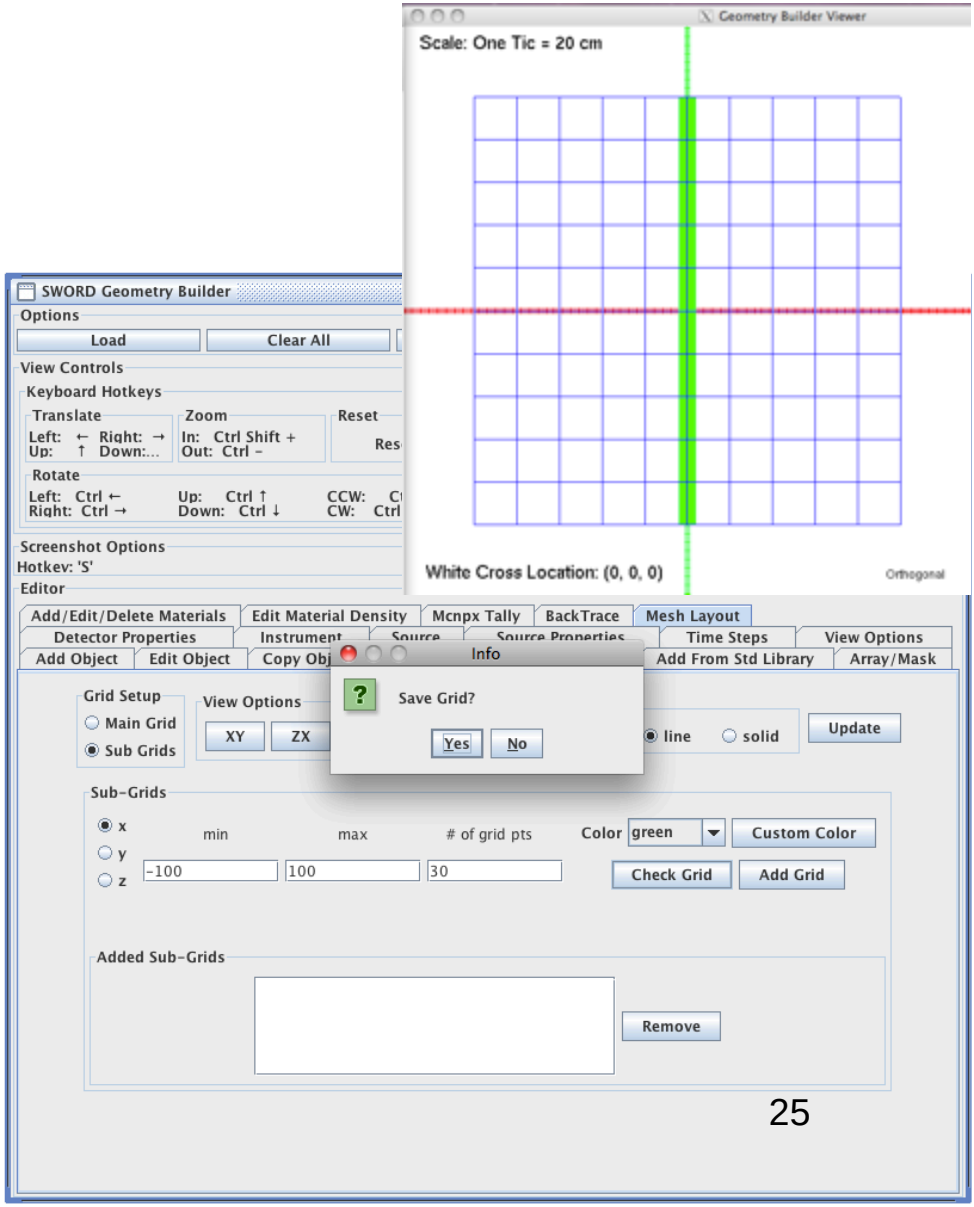
- Improve integration with MCNPX/6
  - Tallies applied to surfaces (F1, F2) or volumes (F4, F6, F8) for any defined detector
  - Tree-view displays user-defined tallies
  - Energy, Time, Cosine ranges and particle type may be defined
- Results viewable using SWORD analysis tools
- Working on mesh tallies, auto-funneling of tallies and “physics wizard”





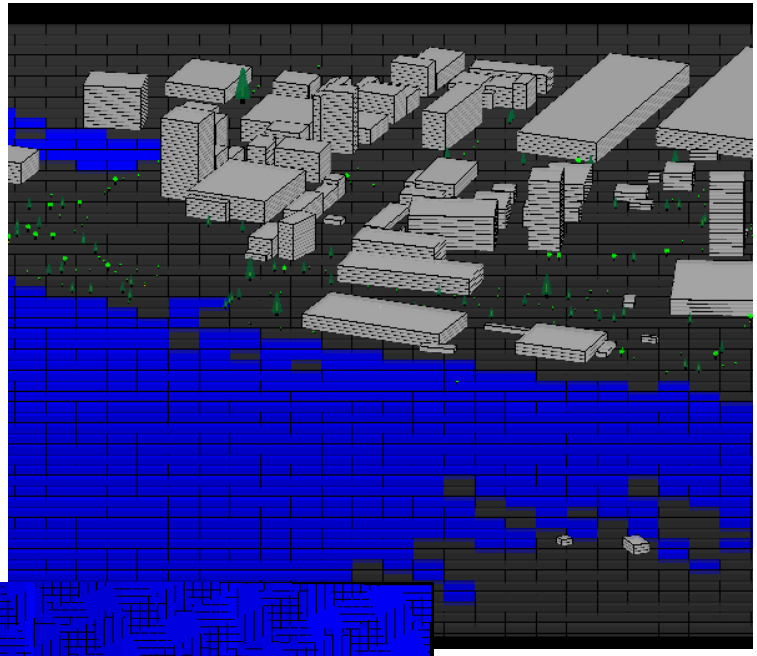
ADVANTG

- AutomateD VAriaNce reducTion Generator (ADVANTG)
  - Developed at ORNL
  - Automatically generated weight-window map for use in MCNP
- Uses ORNL deterministic code (Denovo) to generate weight-windows
  - Can also be used as front end to simulate scenarios deterministically

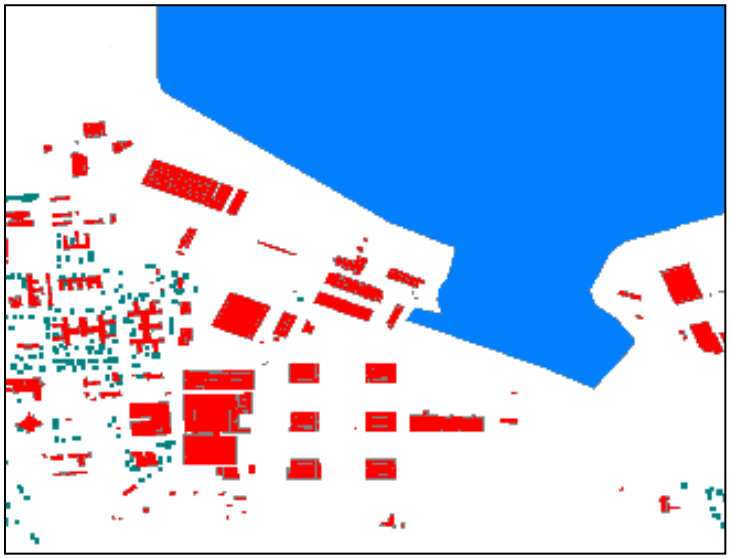


Simulating Cities

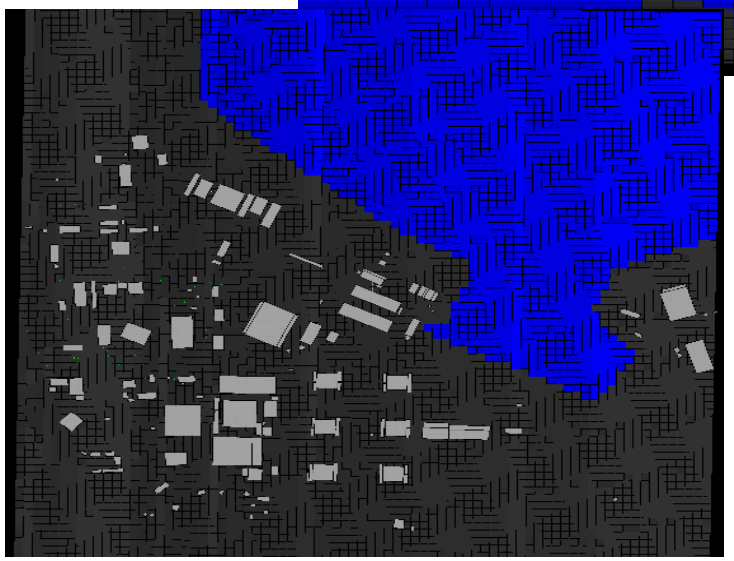
- NRL has developed capabilities to ingest the GIS database of entire cities for use in simulation
  - Building, Elevation, Water, and Trees



GIS

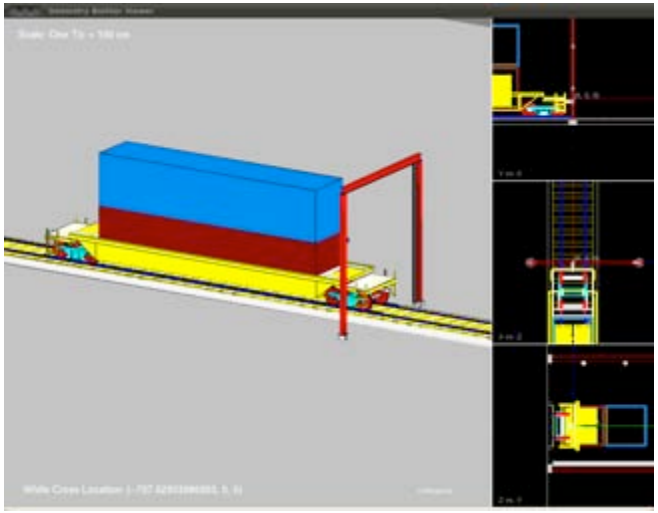


SWORD

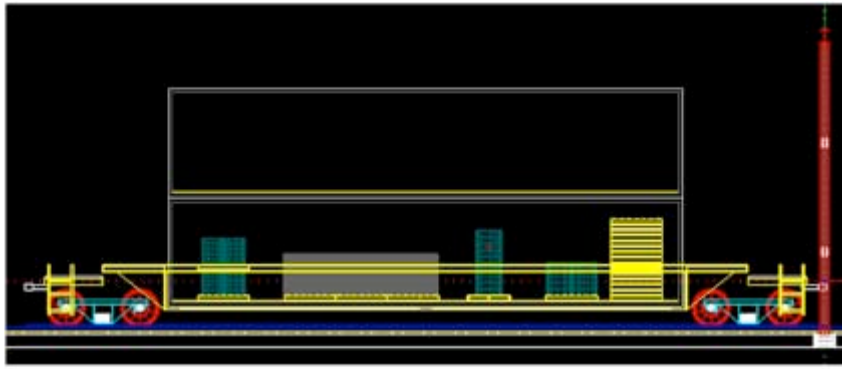


Railroad Radiography

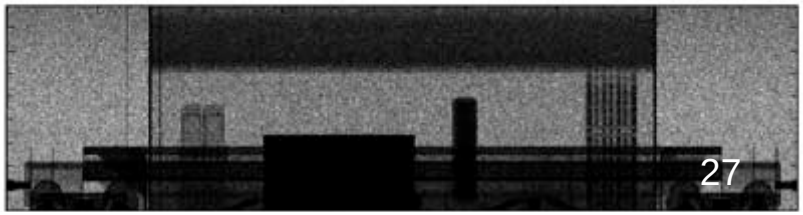
- Simulate radiography with SWORD
- Uses built-in moving objects capability
- Extensive CPU resources may required



SWORD radiography setup

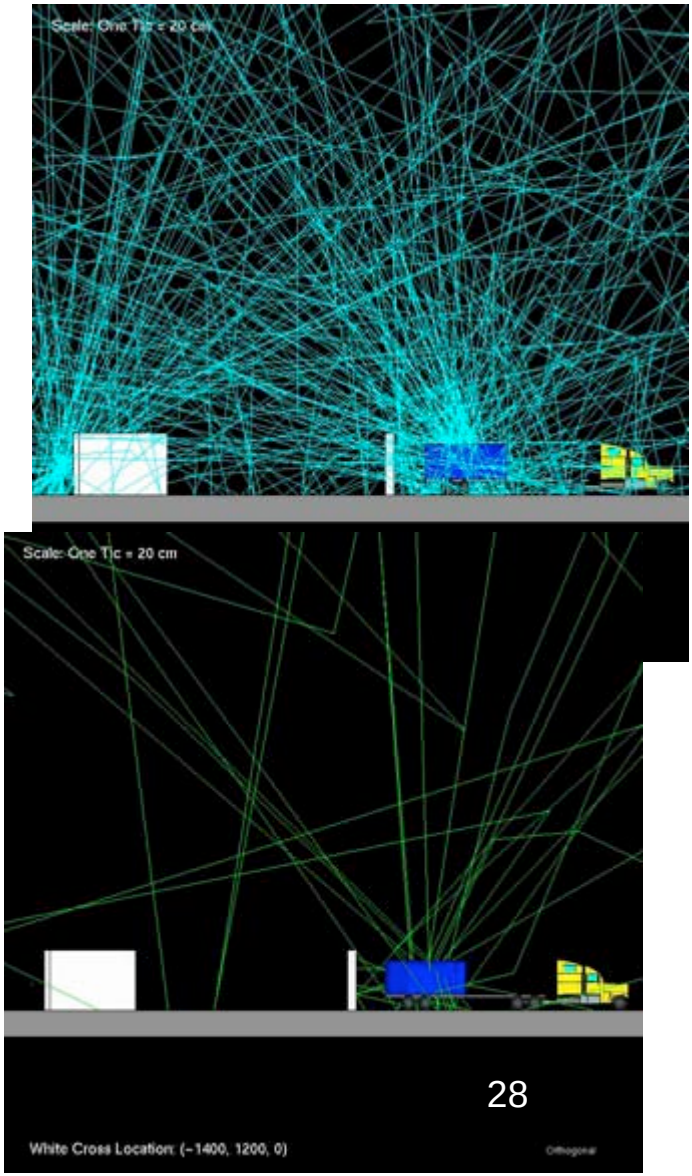


Simulated radiographic image



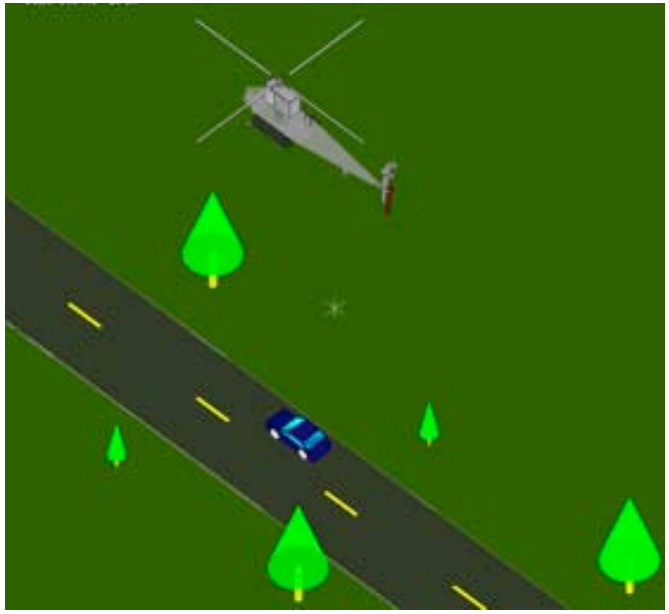
Backtrace

- Backtrace shows the tracks where an interaction occurred in a defined detector
  - Includes energy, particle species, and time information
  - Currently only works with GEANT4
- Example with neutron source
  - 1e6 neutrons fired isotropically from a point source
  - Detector array in a container, on a truck
  - Top Right: cyan tracks show the neutrons that interacted in the detector
  - Bottom Right: green tracks show secondary photons that interact in the detector

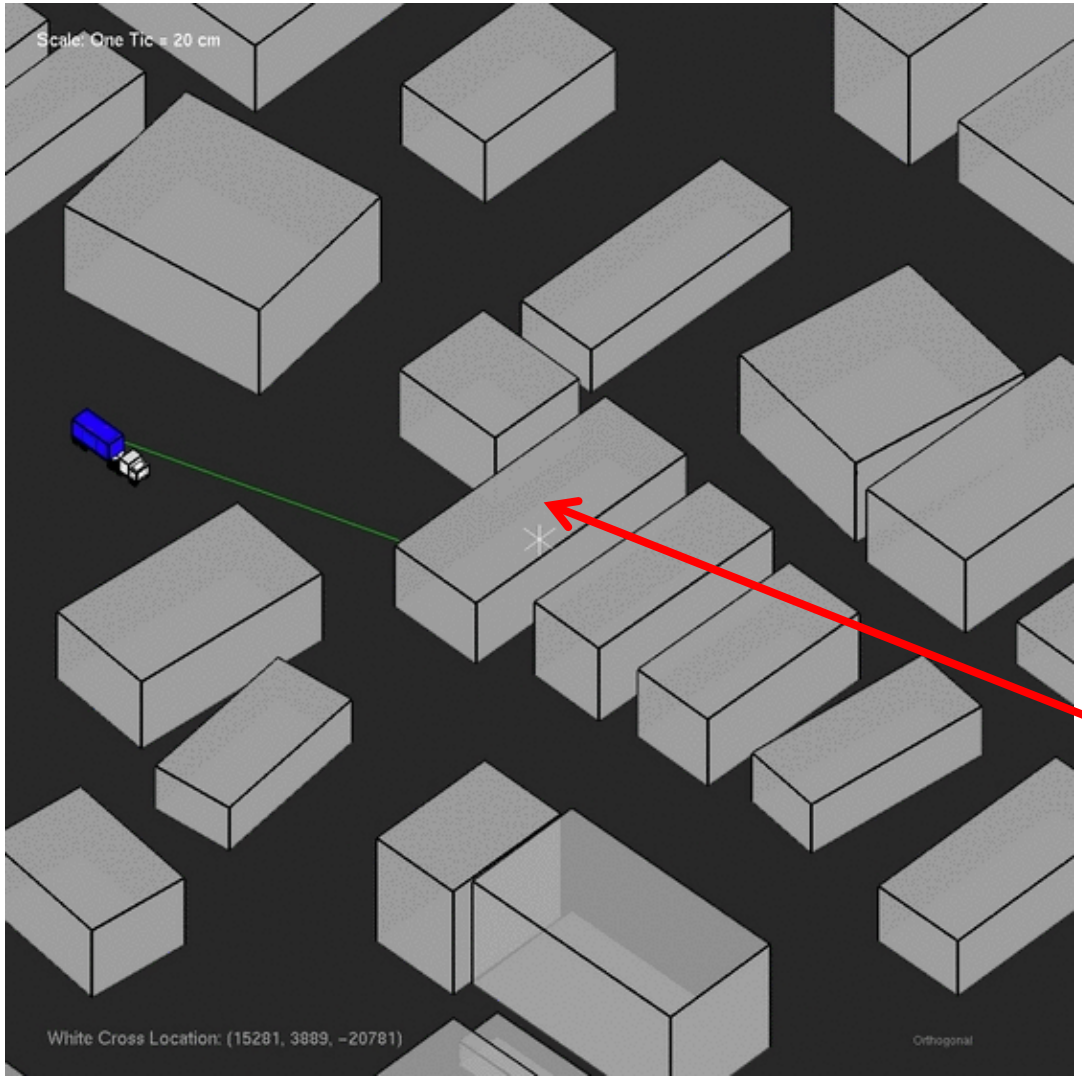


Outline

- Introduction to SWORD
  - Motivation
  - User Interface
  - Standard Library
  - Analysis tools
- SWORD Extensions in Progress
  - MCNPX/6 Adapters
  - ADVANTG Adapters
  - Conversion of GIS data into SWORD
  - Radiography tools
  - Backtrace (GEANT4)
- SWORD in Operational Use
- Conclusions



Detection in Urban Environment

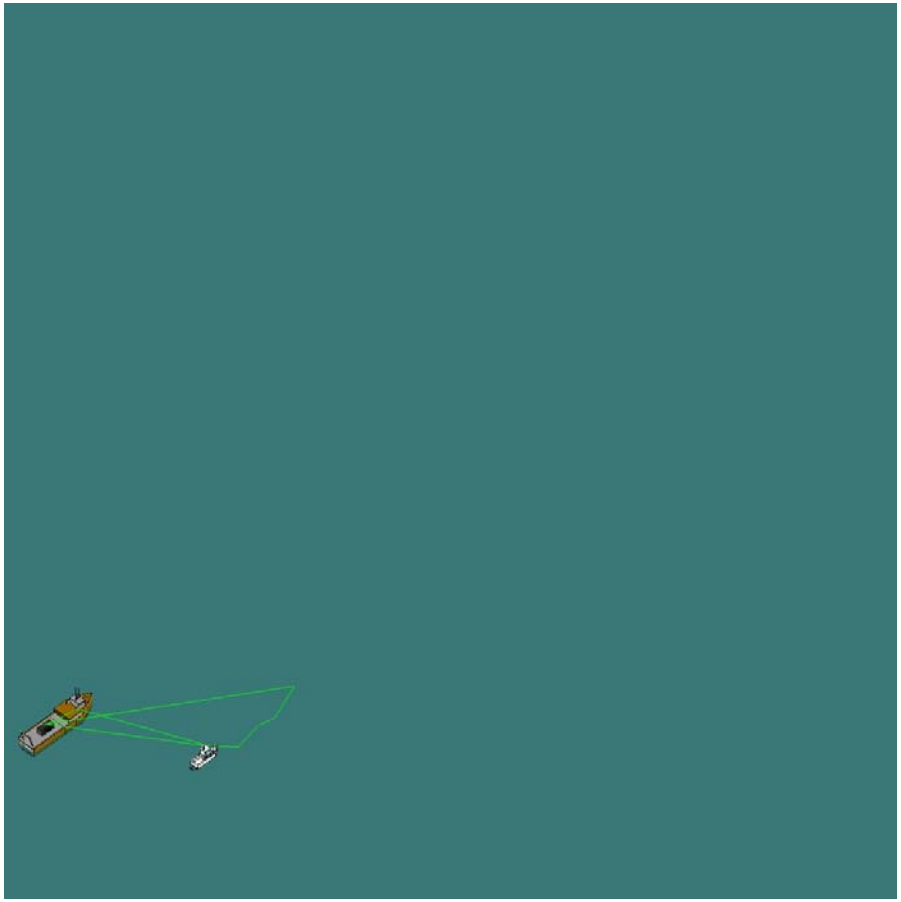


Building containing source

- Seattle buildings created with GIS data
- Source placed in one of the buildings

Detection on Sea Simulation

- Vessel with large area detector
  - 100%-efficient HPGe detectors
  - 6” NaI detectors
  - Moving at 6 knots
- Yacht with source
  - Shielded SNM
  - Moving at 5 knot



Conclusions

- NRL developed SWORD to bring the power of simulation to the non-expert user
- Ease of use along with standard library allows for efficient setup and simulation
- Continually developing SWORD
  - Adding new functionality (suggestions welcome)
  - Improving interface to MC engines
  - Adding interfaces to new engines
- Developing user base (~100 users)

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