Workflow-Oriented Cyberinfrastructure for Sensor Data Analytics

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Four Kinds of Big Data

Archetypal

Science Projects

LHC, SKA, LSST

Business/Industry

Genomics, Finance

Government

NASA, NOAA, DOE

Crowd-Sourced

Social Media

Facebook, Twitter

Recommenders

Yelp, Angie, Groupon

Web Commerce

Amazon, Ebay

Long-tail

Science Projects

Small orgs, RDM

Personal

Hobbies, Citizen Science/Arts

Government

Internal and unpublished

Sensor Streams

Internet of Things

Appliances, Homes

Smart Cities

Energy grids, Transportation

Health

Biosensors, ER,OR

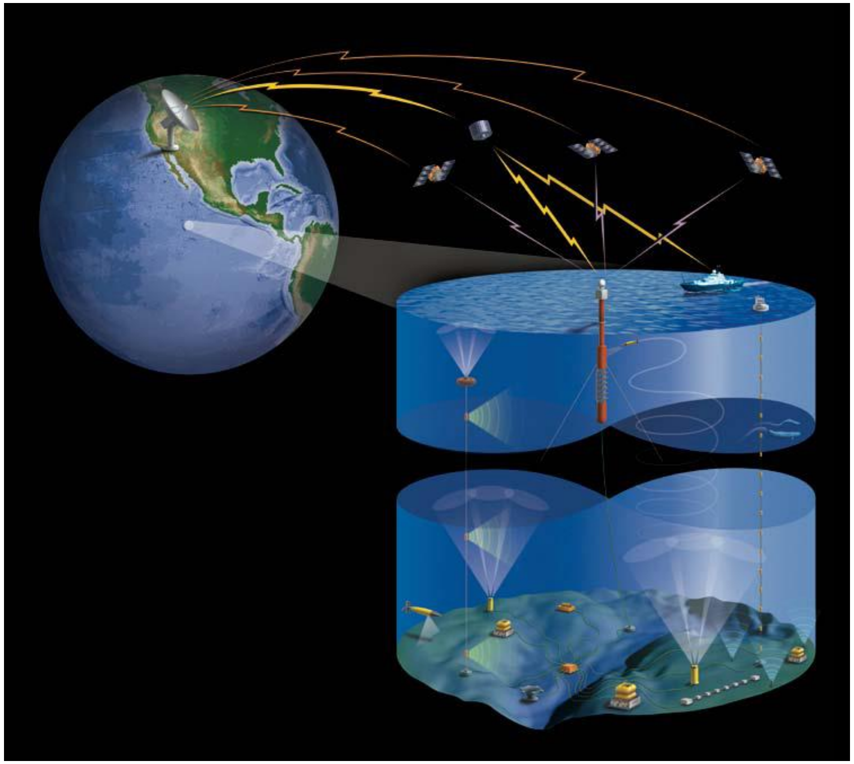
Characterization	Archetypal	Crowd-Sourced	Long-tail	Sensor Streams
Volume	High	High	High	High
Velocity	High	Bursty	Low	High
Variety	Low	High	High	High
Veracity	High	Mixed	Low	Mixed
Value	High	Ephemeral	Unknown	Huge
Findability	High	High	None	None
Availability	High	Short-term	None	Low

Sensor Data

What is a sensor? A sensor acquires a physical parameter and converts it into a signal suitable for processing (e.g. optical, electrical, mechanical)

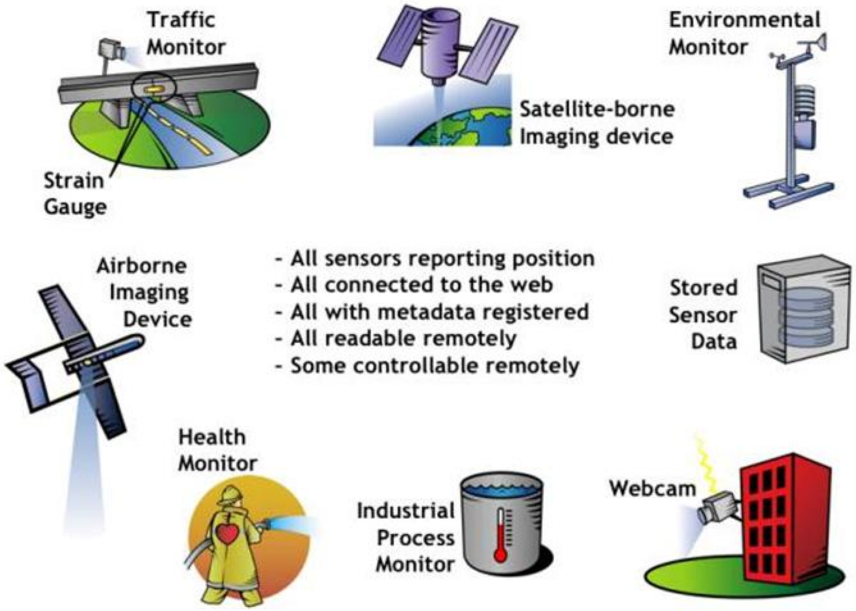
Sensor data have some peculiar properties:

- Highly distributed network
- Time-related
  - Continuous
- Concept of infinite stream
- Volume – small to large packets
- Velocity – slow mostly
- Variety - Disparate
- Fusion is important
- Metadata is important
- Sensor Concentrators



Sensors & DFC

- Multiple partners use sensor data
  - Marine, Seismic & Environment Science (SciON)
  - Hydrology (Hydroshare)
  - Engineering (Smart Cities)
  - Cognitive Science (TDLC)
  - Biology (CyShare)
- DFC development activities:
  - Access to sensor data
    - Access control, Authentication,...
  - Export to Standard formats
  - Archiving of sensor data
    - Reuse & Repurpose
  - Integrated Metadata & Discovery
  - Integrate into Tools & Workflows
  - Playback: Synchronized



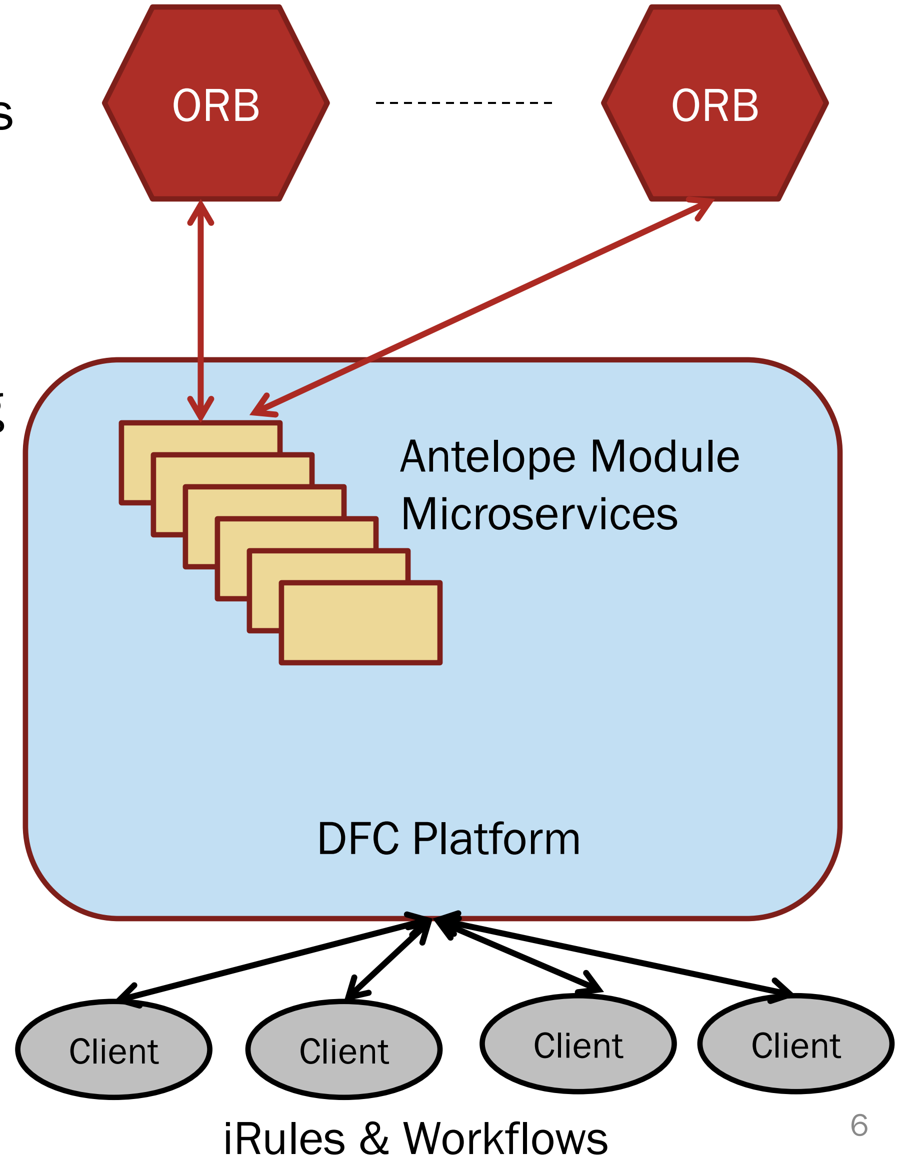
Antelope Real Time System

- Concentrator
  - Used by multiple projects
  - High performance Object Ring Buffer
  - Multiple types of sensor
  - Stream processing
  - Network of ORBs
  - Used by UCSD SIO

BRTT.COM

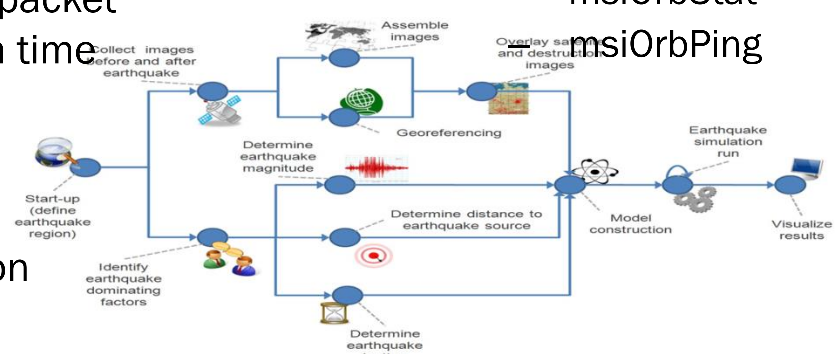
DFC & Antelope

- Loosely-coupled federation
- Connection through Microservices
- Can define MSO for each orb stream
- Can be added to Workflows
- Provide access without burdening ARTS Administrators
- Implementation:
  - Reap Sensor Streams
  - Convert Formats
  - Store Streams as Files
  - Access Packets from Files
  - Push Files as Streams
  - Use Rules to Archive



DFC Antelope Microservices

- Single Packet Microservices
  - msiAntelopeGet - get a packet
  - msiAntelopePut - put a packet
- Connection Microservices
  - msiOrbOpen
  - msiOrbClose
  - msiOrbTell - redirect to an orb
- Stream-level Microservices
  - msiOrbSelect - select streams
  - msiOrbReject - reject streams
  - msiOrbPosition – position read pointer by packetid
  - msiOrbSeek - position read pointer by skipping packet
  - msiOrbAfter – seek with time
- Other Helpers
  - convertExec – format conversion
  - readLine
- Packet Low-level Access (read, write) Microservices
  - msiOrbGet - get current packet
  - msiOrbReap - get next packet
  - msiOrbReapTimeout
  - msiOrbPut – push a packet
- Packet Manipulation Microservices
  - msiOrbUnstuffPkt
  - msiFreeUnstuffPkt
  - msiOrbDecodePkt
  - msiOrbStuffPkt
  - msiOrbEncodePkt
- ARTS Heartbeat Microservices
  - msiOrbStat
  - msiOrbPing



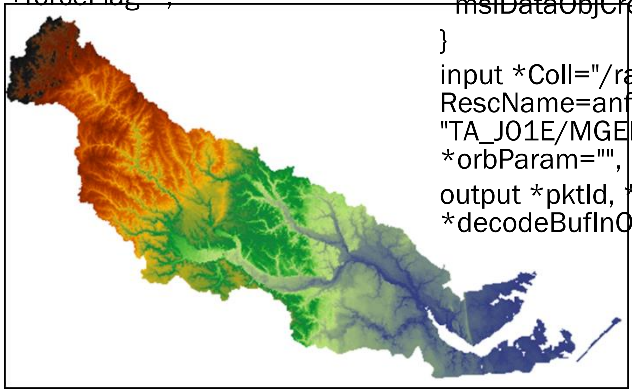
Reaping Rules

Continuous Reaper

```
antelopRule{
 delay("<PLUSET>30s</PLUSET><EF>10m</EF>") {
   msiAddKeyVal(*KVP,"selectCriteria",*pktSelectInfo);
   msiAntelopeGet(*pktSelectInfo, *firstPktId, *lastPktId,
                        *NumOfPkts,*outBufParam);
   *SColl = *Coll ++ "/" ++ *Sensor
   *SFile = *SColl ++ "/" ++ "*firstPktId" ++ "_" ++ "*lastPktId" ++ ".data";
   msiCollCreate(*SColl,"1",*STAT_1);
   msiDataObjCreate(*SFile, *Resc, *D_FD);
   msiDataObjWrite(*D_FD, *outBufParam, *WR_LN);
   msiDataObjClose(*D_FD,*STAT_2);
   msiAddKeyVal(*KVP,"firstPktId","*firstPktId");
   msiAddKeyVal(*KVP,"lastPktId","*lastPktId");
   msiAddKeyVal(*KVP,"numOfPkts","*NumOfPkts");
   msiAssociateKeyValuePairsToObj(*KVP, *SFile, "-d");
  }
  writeLine("stdout", "Delayed Rule Launched");
}
input
*pktSelectInfo="<ORBHOST>anfexport.ucsd.edu:cascadia</ORBHOST>
<ORBSELECT>TA_M04C/MGENC/EP40</ORBSELECT>
<ORBWHICH>ORBOLDEST</ORBWHICH>
<ORBNUMOFPKTS>8</ORBNUMOFPKTS>
<ORBNUMBULKREADS>4</ORBNUMBULKREADS>",
*Resc="destRescName=anfdemoResc++++forceFlag=",
*Coll="/rajaanf/home/rods/SensorData",
 *Sensor= "TA/M04C/MGENC/EP40"
output ruleExecOut
```

Reap and Convert

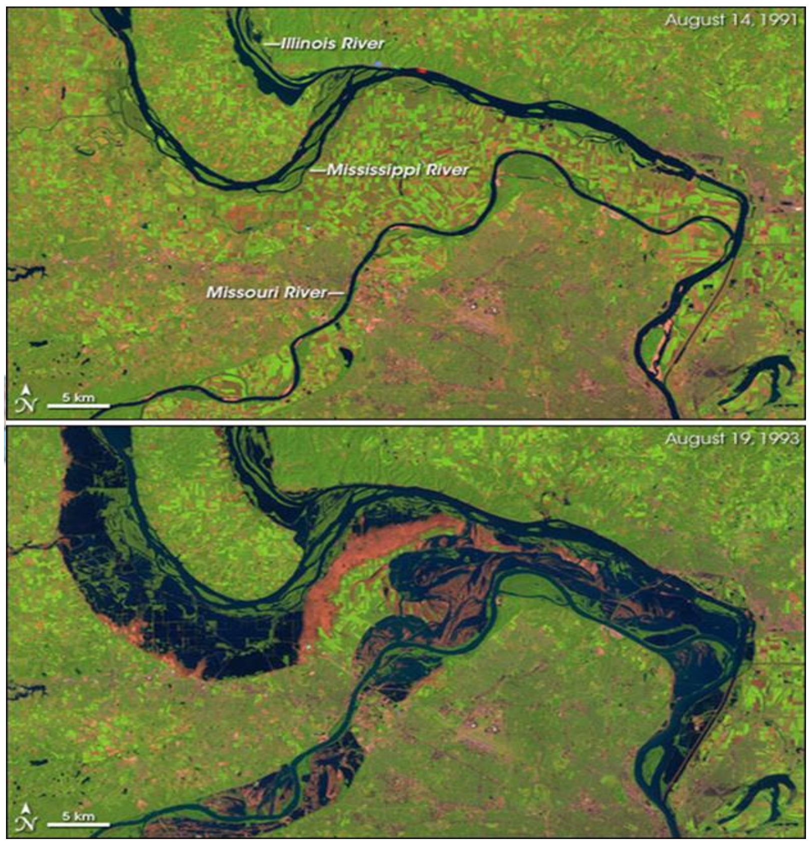
```
antelopRule{
#Get Packet
 msiOrbOpen(*orbHost,*orbParam, *orbId);
 msiOrbSelect(*orbId, *Sensor,*sresOut);
 msiOrbReap(*orbId, *pktId, *srcName, *oTime, *pktOut, *nBytes,
                *resOut);
 msiOrbDecodePkt(*orbId, *modeIn, *srcName, *oTime, *pktOut,
                                *nBytes, *decodeBufInOut);
 msiOrbClose(*orbId);
#Store Packet
 *SColl = *Coll ++ "/" ++ *Sensor
 *SFile = *SColl ++ "/" ++ "waveform.data";
 msiCollCreate(*SColl,"1",*STAT_1);
 openForAppendOrCreate(*SFile, *Resc, *D_FD);
 msiDataObjWrite(*D_FD, *decodeBufInOut, *WR_LN);
 msiDataObjClose(*D_FD,*STAT_2);
}
openForAppendOrCreate(*SFile, *Resc, *D_FD) {
  *SObj = "objPath=" ++ *SFile ++ "++++openFlags=O_RDWR";
  msiDataObjOpen(*SObj, *D_FD);
  msiDataObjLseek(*D_FD, *Offset,*Loc,*Status1);
}
openForAppendOrCreate(*SFile, *Resc, *D_FD) {
  msiDataObjCreate(*SFile, *Resc, *D_FD);
}
input *Coll="/rajaanf/home/rods/newsenstest",*Resc="dest
RescName=anfdemoResc++++forceFlag=", *Sensor=
"TA_J01E/MGENC/SM100", *orbHost="anfexport.ucsd.edu:cascadia",
*orbParam="", *modeIn=2, *Offset="0", *Loc="SEEK_END"
output *pktId, *srcName, *oTime, *nBytes, *pktOut,
*decodeBufInOut, ruleExecOut
```



Ingest Rules

Interactive Packet Ingestion

```
antelopRule{
   msiAntelopePut(*orbName, *srcName, *timeStamp,
          *pktPayLoad);
}
input *orbName="anfdevl.ucsd.edu:demo",
          *srcName="DFC_UNC/ch/T1", *timeStamp="",
          *pktPayLoad=$"test 3 string"
output ruleExecOut
```



Orb2Orb: Reaped Packet Ingestion

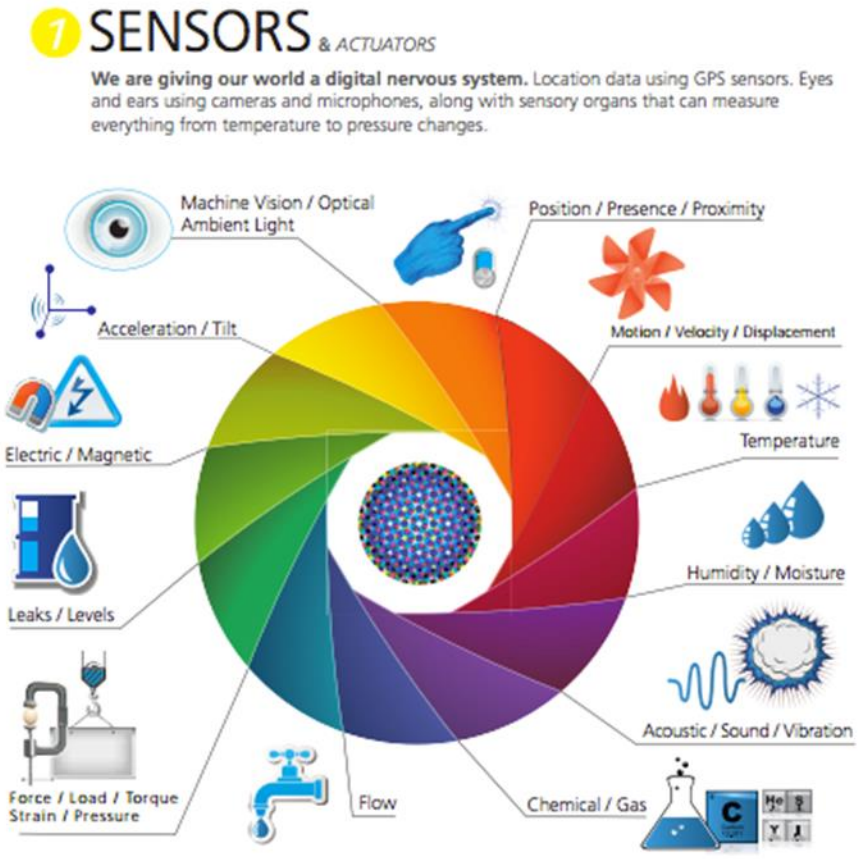
```
#get a MGENC packet  from cascadia and put it in demo
# also write also in a file to compare
antelopRule{
# get the packet and the write into file
    msiAntelopeGet(*pktSelectInfo, *firstPktId, *lastPktId,
             *NumOfPkts,*outBufParam);

   *SColl = *Coll ++ "/" ++ *Sensor
   *SFile = *SColl ++ "/" ++ "*firstPktId" ++ "_" ++ "*lastPktId" ++ ".data";
   msiCollCreate(*SColl,"1",*STAT_1);
   msiDataObjCreate(*SFile, *Resc, *D_FD);
   msiDataObjWrite(*D_FD, *outBufParam, *WR_LN);
   msiDataObjClose(*D_FD,*STAT_2);

# write to  orb
   msiAntelopePut(*orbName, *srcName, *timeStamp, *outBufParam);
}
input *pktSelectInfo="<ORBHOST>anfexport.ucsd.edu:cascadia</ORBHOST>
<ORBSELECT>TA_J01E/MGENC/SM1</ORBSELECT>
<ORBWHICH>ORBOLDEST</ORBWHICH>
<ORBNUMOFPKTS>1</ORBNUMOFPKTS>
<ORBNUMBULKREADS>1</ORBNUMBULKREADS>
<ORBPRESENTATION>ONEPKT</ORBPRESENTATION>",
*Resc="destRescName=anfdemoResc++++forceFlag=",
*Coll="/rajaanf/home/rods/SensorData", *Sensor="TA_J01E_MGENC_SM1",
*orbName="anfdevl.ucsd.edu:demo
", *srcName="DFC_UNC/MGENC/T1", *timeStamp=""
output *outBufParam, *firstPktId, *lastPktId, *NumOfPkts,  ruleExecOut
```

Sensor Data in DFC

- Sensor streams are stored as files in DFC:
  - Raw Orb format – buffer
  - CDL format - Common Data form Language a human-readable text representation of *netCDF* data
  - NC format: NetCDF Format
    - NetCDF 4 – version 4
    - HDF5 compatible
    - Use ‘ncgen’ for conversion
  - JSON – human-readable format

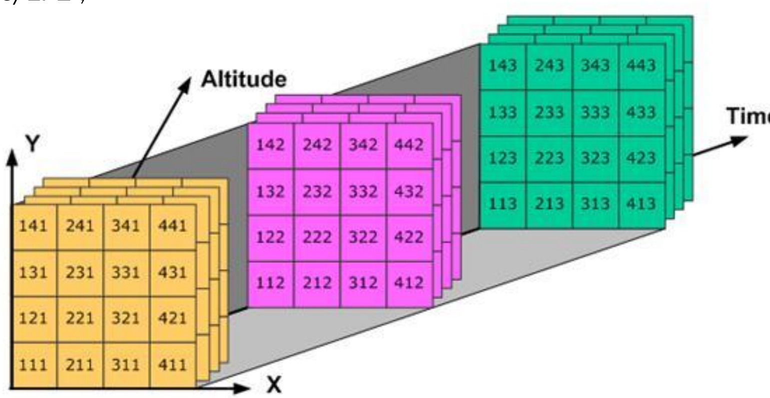


- Multi-type Sensor’s reaped
  - Seismic Sensor
    - 3 sensor measurement per packet
    - North, East, Vertical Movements
  - Pressure Sensor
    - 2 sensor measurement per packet
    - Barometric Pressure, Infrasound

Sample Data Files

CDL Format
Pressure Data

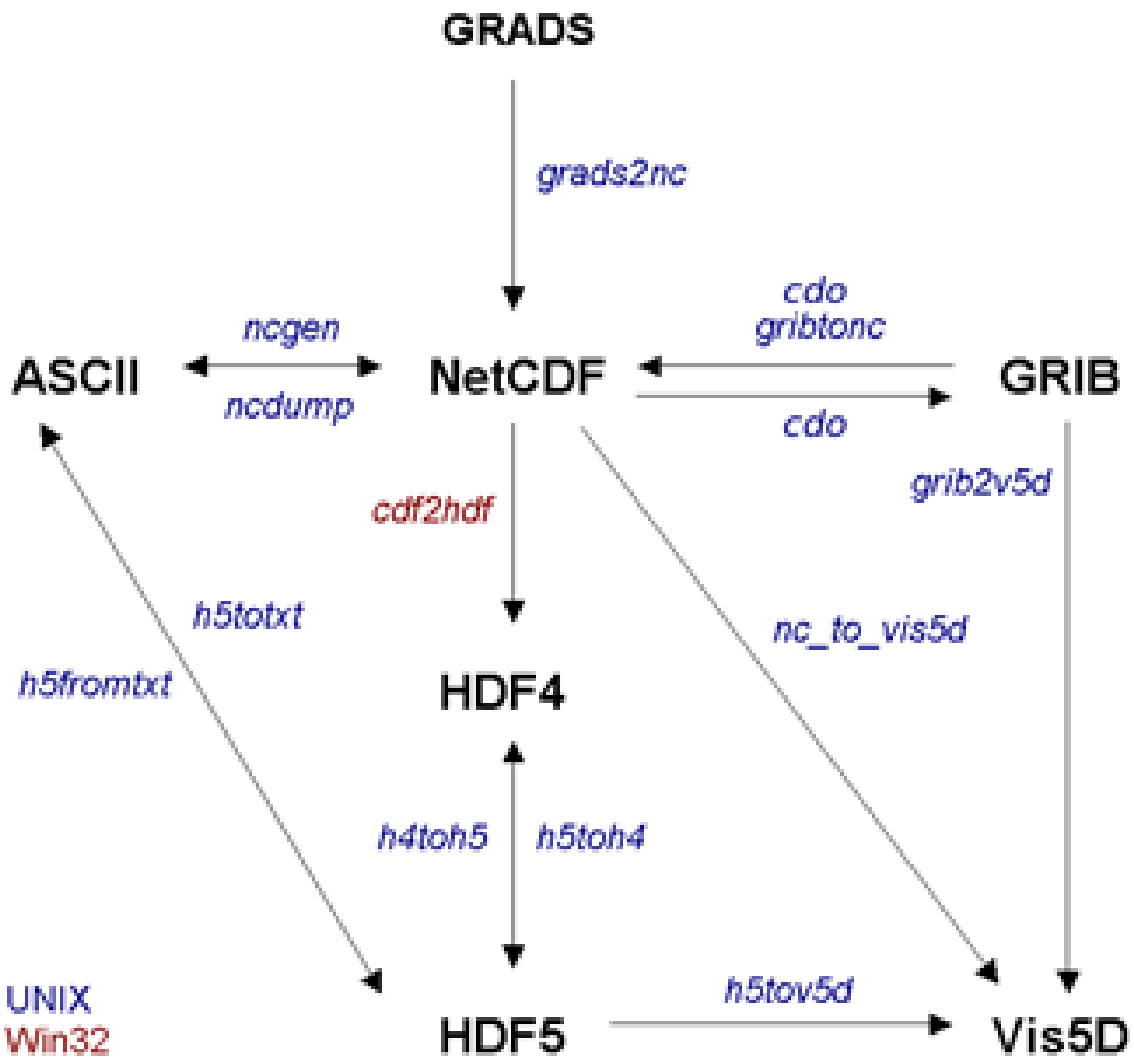
```
netcdf barometric_pressure {
types:
 compound pressure_vector_t {
   double  timestamp;
   float pressure ;
   float infrasound ;
 }; // barometric_vector_t
dimensions:
      time = UNLIMITED;
variables:
            pressure_vector_t barometric(time) ;
             barometric:standard_name = "two vector barometric pressure
data" ;
             barometric:long_name = "Barometric" ;
// global attributes:
      :srcname = "TA_003E/MGENC/EP1";
      :packettype = "waveform";
      :net = "TA";
      :sta = "003E";
      :chan = "LDO";
      :loc = "EP";
      :sampratepersec = " 1.000";
      :calib = "          1";
      :calper = "-1.000";
      :segtype = "5s";
      :nsamps = "120";
      :epochtime = "1446064294.9710000";
      :epochstarttime = "Wed 2015-301 Oct 28 20:31:34.97100";
      :epochendtime = "20:33:34.97100";
data:
barometric =
      {1446064294.9710000,   717022,   10159},
      {1446064295.9710000,   717021,    8821},
      {1446064296.9710000,   717023,   15918},
      {1446064297.9710000,   717026,   21402},
```



JSON Format
Seismic Data


```
{
 "packets":[
 {
      "srcname":"TA_J01E/MGENC/SM100",
      "pkttime":" 6/25/2015 (176)  0:30:23.968",
      "bytes":"535",
      "packettype":"waveform",
      "channels":[
      {
           "channum":" 0",
           "net":"TA",
           "sta":"J01E",
           "chan":"HNZ",
           "loc":"",
           "sampratepersec":"100.000",
           "calib":"          1",
           "calper":"-1.000",
           "segtype":"5s",
           "nsamps":"100",
           "epochtime":"1435192223.9683931",
           "epochstarttime":"Thu 2015-176 Jun 25
                      0:30:23.96839",
           "epochendtime":" 0:30:24.96839",
           "data":[
                {"v":"  -52727"},
                {"v":"  -52729"},
                {"v":"  -52729"},
                {"v":"  -52731"},
```

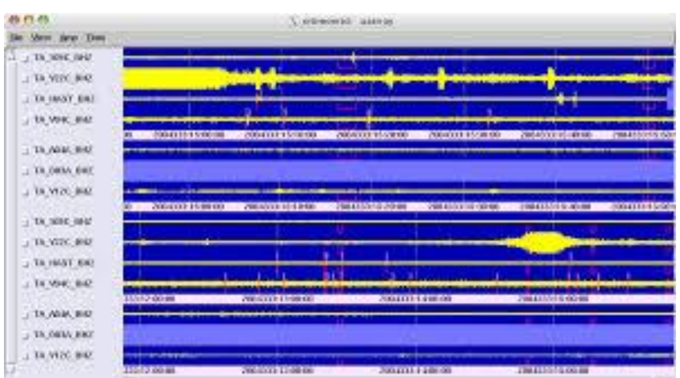
Formats

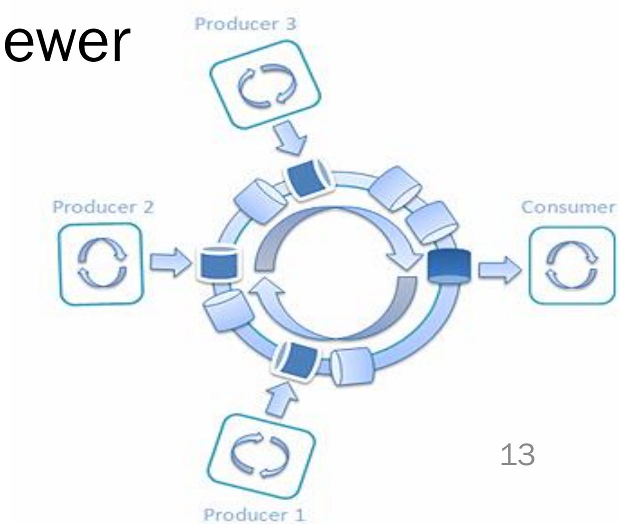

GRADS
grads2nc
ASCII
ncgen
ncdump
NetCDF
cdo
gribtonc
cdo
GRIB
grib2v5d
cdf2hdf
h5totxt
h5fromtxt
nc_to_vis5d
HDF4
h4toh5
h5toh4
UNIX
Win32
HDF5
h5tov5d
Vis5D

Types of Operation Supported

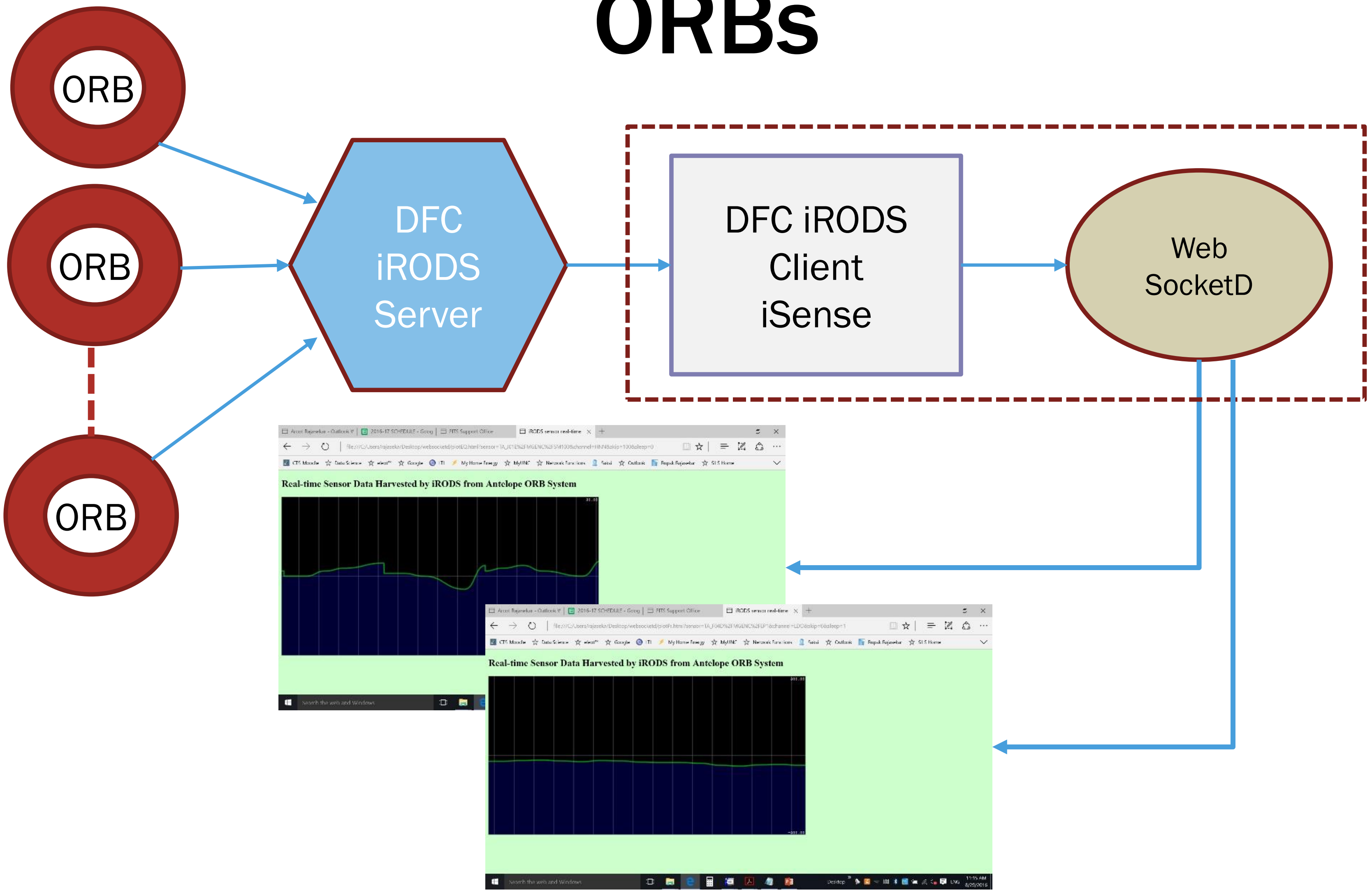
- Reap 8 Packets as buffers
- Low level Reap
- Archive One Packet in JSON Format
- Archive Multiple Packet in NetCDF CDL Format
- Archive Pressure Data in NetCDF CDL Format
- Convert CDL to NC Format

- Ingest Character Packet
- Access Ingested Packet
- Orb2Orb Copy of Seismic Waveform Packet
- Access NetCDF File from DFC using Cloud Browser
- Show Plots Using HDFViewer

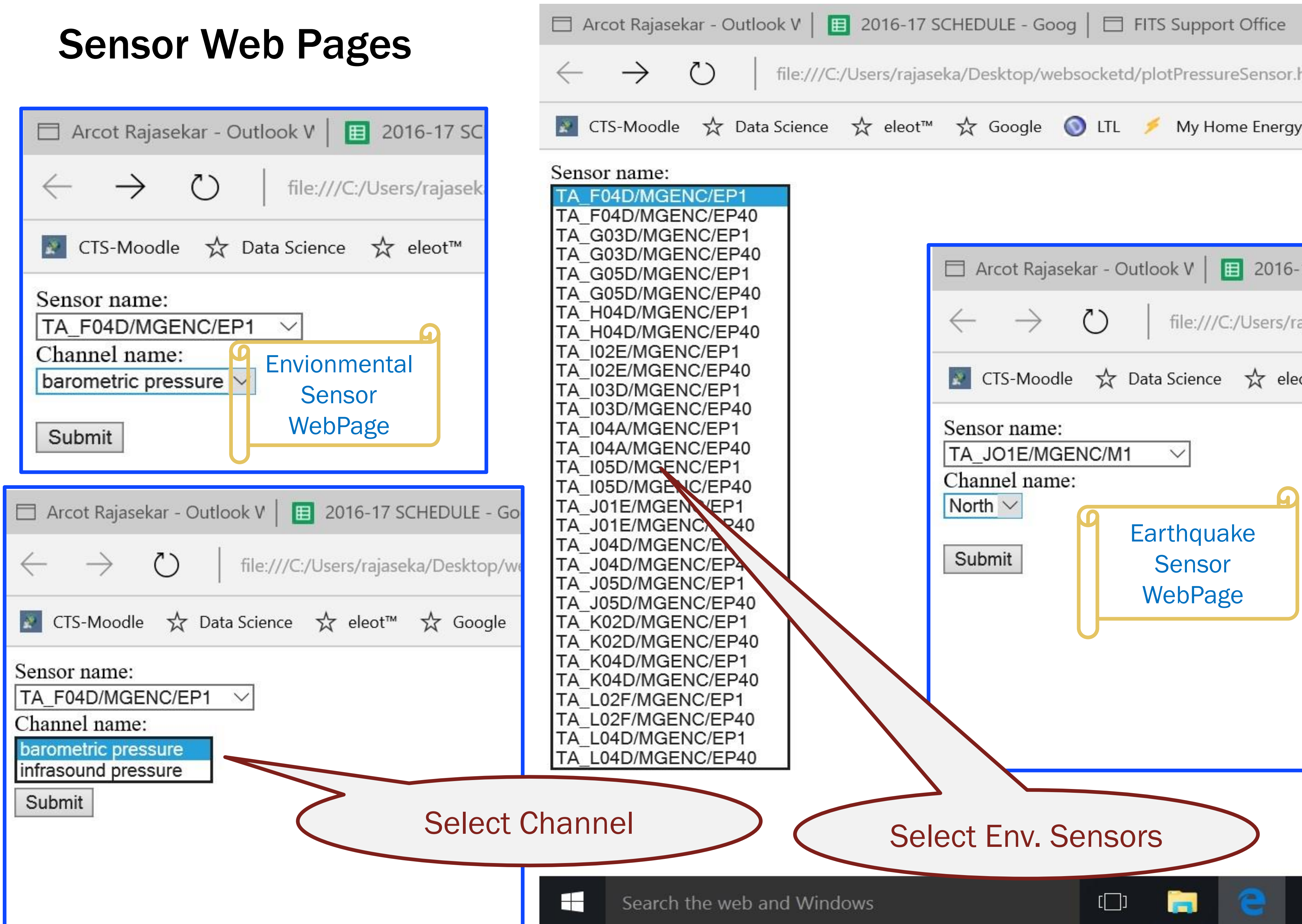




Real-time Sensor Data from ORBs



Sensor Web Pages



Conclusion

- Real-time Access to Sensor Data
  - Not just archiving
- Access to any sensor that is available through an ORB
  - No need for registration
- Control sensor data flow
  - Select Sensor
    - From multi-sensor packet streams
  - Sub sample
    - For high frequency data
    - Eg. Send only one value per second
  - Stretch data flow
    - From multi-value packets
    - Eg. 60 per second values in single packet
- Provision Access through the web
  - Using websocketd