Statement of Work
For Implementing Arrangement #19
Development of a High-Resolution Quantitative Precipitation Estimation and Quantitative Precipitation Forecast (HRQ2) System
Between the Taipei Economic and Cultural Representative Office in the United States And the American Institute in Taiwan

1.0 - Background and Objectives

This Statement of Work addresses tasks that will be undertaken by the joint team of the Global Systems Division (GSD) of the Earth System Research Laboratory, (ESRL), the designated representative of the American Institute in Taiwan (AIT) and personel of the Central Weather Bureau (CWB), the designated representative of the Taipei Economic and Cultural Representative Office in the United States (TECRO) in accordance with the terms of Implementing Arrangement #19 of the Agreement between the Taipei Economic and Cultural Representative office in the United States and the American Institute in Taiwan for Technical Cooperation in Meteorology and Forecast Systems Development, which provides for technical cooperation between TECRO's designated representative, the Taiwan Central Weather Bureau (CWB) and AIT's designated representative, the U.S. National Oceanic and Atmospheric Administration's Global Systems Division (NOAA/ESRL/GSD). The two designated representatives cooperate on the development of meteorology and forecast systems.

The WFO-Advanced system currently under development at the NOAA's GSD of the ESRL in Boulder, Colorado, has been deployed as an essential part of the AWIPS (Advanced Weather Interactive Processing System) for the U.S. National Weather Service (NWS). The WFO-Advanced system development has been a very important cooperative activity between CWB and NOAA/ESRL/GSD.

The WFO-Advanced system is a realization of the generic FX-Advanced (GSD X-window Advanced) system. Figure 1 illustrates the WFO-Advanced components:

- National and local data feeds
- GSD's Local Analysis and Prediction System (LAPS)
- Quantitative Precipitation Estimation and Segregation Using Multiple Sensors (QPE-SUMS)
- Geographical Information System (GIS) data
- The interactive display system (D2D)
- The AWIPS Forecast Preparation System (AFPS)
- 3-D visualization
- Hydrological applications developed at the NWS Office of Hydrology
- A component that contains General X applications
- Local Data Acquisition and Dissemination System (LDAD)

Two tasks are included in the Statement of Work: (1) the development of a High-resolution Quantitative Precipitation Estimation and Quantitative Precipitation Forecast (HRQ2) System, (2) continuing integration on earlier cooperative projects, such as data support and forecast workstation upgrade.

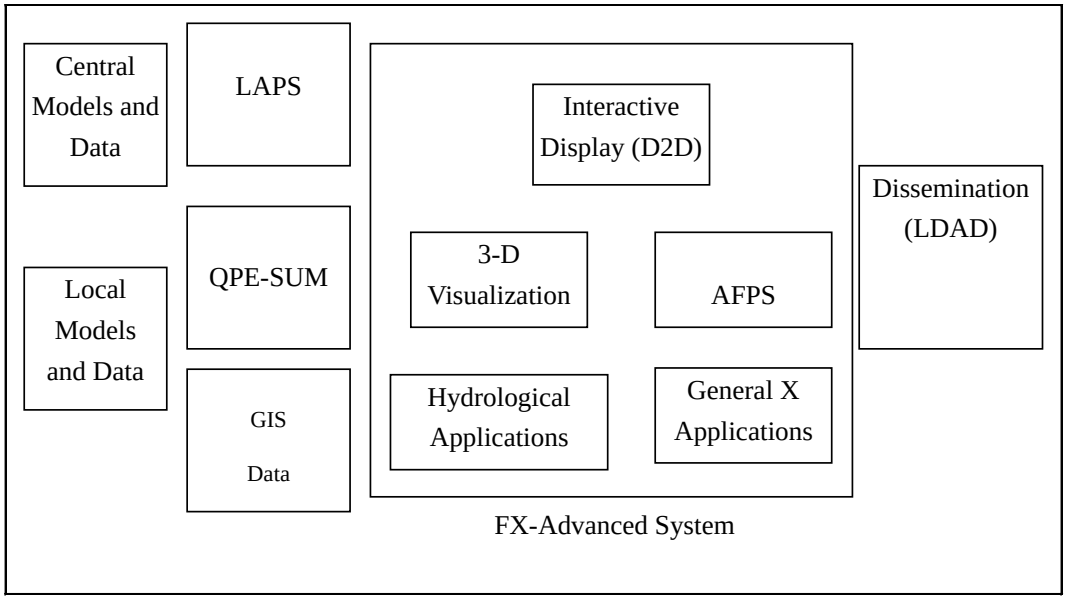

Figure 1 WFO-Advanced

The tasks will be undertaken by the CWB-NOAA/ESRL /GSD Joint Team as the the designated representatives of the TECRO and AIT working at the NOAA/ESRL/GSD facility in Boulder, Colorado, and by CWB staff at the CWB facility in Taipei, Taiwan, as appropriate. This Statement of Work addresses only tasks that will be undertaken by the CWB-NOAA/ESRL/GSD Joint Team under the terms of Implementing Arrangement #19. It describes the performance period, deliverables, and resource requirements.

2.0 - Task Descriptions

In terms of the overall program schedule, the following two tasks have been identified as being critical during the January 1 to December 31, 2007, time period. These are listed below, along with the estimated proportion of resources that is to be allocated to each task.

- Task #1 – High-Resolution Quantitative Precipitation Estimation and Quantitative Precipitation Forecast (HRQ2) System
- Task #2 – Continuing interaction on earlier cooperation projects

These two tasks are described in more detail below.

Task #1 - High-Resolution Quantitative Precipitation Estimation and Quantitative Precipitation Forecast (HRQ2) System

During Implementing Arrangement #18, CWB and NOAA/ESRL/GSD continued to focus on the Quantitative Precipitation Forecast (QPF) for water accumulation and debris flow based on a new advanced 3D variational (3DVAR) data assimilation scheme as NOAA/ESRL/GSD's part of HRQ2 task. This new task will support the operational needs from threats from flash flood, debris flow and landslide. Motivated by CWB's request to establish a 3-D variational approach for the model initialization, TECRO's and AIT's designated representatives, CWB and NOAA/ESRL/GSD

respectively, selected to implement the GSI (Gridpoint Statistical Interpolation) analysis system which is used operationally by NOAA/NCEP (National Centers for Environmental Prediction). The GSI package is customized for CWB for the input data format in order to ingest CWB's own data. The initial CWB GSI package was tested and evaluated near the end of June 2006 with radar data and conventional observation data. GSI is set up for ingest of both radar radial velocities and satellite radiance data. For work in 2007, an effort will be required to assess the availability of satellite radiance data from geosynchronous or polar orbiting satellites and to write the software to deliver this to GSI. Satellite radiance data will enhance the analysis in the oceanic areas surrounding Taiwan. Before GSI can be utilized for short term precipitation forecasting, a diabatic scheme similar to that already in LAPS must be added to the GSI capability. During Implementing Arrangement #19, CWB and NOAA/ESRL/GSD will continue to include additional new observation data available for LAPS GSI.

GSI has the capability of ingesting model error statistics (variances) for optimizing its analysis. For this time phase, the ensemble error statistics are made up of sequential runs of the background model (either NFS15 or WRF). Error will be recovered from an independent analysis and statistics generated. These statistics will be updated within GSI to optimize the analysis at any time.

The new focus is to adopt a multiscale 3DVAR analysis scheme called STMAS (Space and Time Mesoscale Analysis System) as part of LAPS III for surface observations and other remote sensing data such as radar data. STMAS will be extended to 3DVAR and eventually a 4DVAR approach. In its 3DVAR version, STMAS will provide multiscale analysis using an inhomogeneous observation distribution. Like GSI, STMAS can make use of updating error statistics and can be configured with a diabatic capabiltiy. These two large efforts (GSI and STMAS) may need to be prioritized by CWB management.

STMAS uses a sequence of variational minimization in both the space and time domains to obtain multi-scale grid analysis, which cannot be done through a single 3DVAR analysis. At NOAA/ESRL/GSD, STMAS is currently running every 15 minutes in real time using dense surface observation data. The STMAS analysis provides a good verification tool for high resolution model forecasts.

During Implementing Arrangement #19, TECRO's and AIT's designated representatives CWB and NOAA/ESRL/GSD respectively, will extend STMAS development from using only surface data to include remote sensing data from CWB's advanced radar network, and maybe satellite data. The goal is to develop STMAS as an advanced operational nonlinear analysis tool at CWB in Taiwan to improve local analysis and more importantly provide a prediction system during severe weather. An advantage

of STMAS is that it has been developed at NOAA/ESRL/GSD and is not subject to unexpected changes or upgrades as would be GSI.

NOAA/ESRL/GSD has developed and accessed techniques to measure atmospheric Integrated Precipitable Water (IPW) values using ground-based Global Positioning System (GPS) receivers since 1993. The NOAA GPS-IPW network currently consists of 405 sites. There are three types of sites in the network; NOAA Wind Profilers Sites (NPN), Other NOAA Sites (ONS), and Other Agency Sites (OAS). The network is controlled by a software processing system developed by NOAA/ESRL/GSD. The current ground-based GPS-Met observing software system consists of data acquisition, geodetic modeling, IPW processing and data evaluation, display and dissemination.

During Implementing Arrangement #19, TECRO's and AIT's designated representatives CWB and NOAA/ESRL/GSD respectively, will ingest GPS observation data from the CWB GPS-Met network and process these data using the current NOAA GPS-Met Observing System. NOAA/ESRL/GSD then will transfer IPW values back to CWB for evaluation.

The following summarizes the schedule and resources required for the NOAA/ESRL/GSD part of Task #1:

Performance Period:	35.3 % CWB/NOAA/ESRL/GSD
1. STMAS/GSI 3DVAR data assimilation software (on-line version)	11/30/07
a. conventional data ingest development	8/31/07
b. STMAS 3D variational analysis is extended using conventional data	11/30/07
c. Improve radar data and adding polar orbiting satellite data into GSI 3D variational analysis	11/30/07
2. Establishment of ensemble based error statistics generator for input into GSI or STMAS	11/30/07
3. GSI software update	11/30/07
4. IPW values using CWB GPS-Met network	11/30/07

AIT's designated representative NOAA/ESRL/GSD understand that the National Severe Storms Laboratory (NSSL) will continue research towards the refinement, development, and maintenance of applications required for the Central Weather Bureau (CWB), Water Resources Agency (WRA) and the Soil and Water Conservation Bureau (SWCB) operations. The NSSL research is directed towards improving the monitoring and prediction of flash floods and severe storm identification and short-term forecasting for the Taiwan environment. The NSSL research and development for IA#19 will focus the implementation of advanced QPE and VSQPF techniques as per: 1) implementation of a new HRQ2 infrastructure and code set, 2) the implementation of an advanced radar quality control specifically tuned for the Taiwan environment; 3) 500 meter resolution product generation; 4) assessment in using dual polarization radar for radar intercomparison and calibration; 5) verification

and assessment of application performance.

The following summarizes the schedule and resources required for the NSSL on behalf of AIT's designated representative NOAA/ESRL/GSD part of Task #1:

Performance Period:	35.3 CWB/NSSL	%

Deliverables and Schedule:

1. Define HRQ2 system components and data ingest modules	3/31/07
2. Provide to CWB new HRQ2 executables configured for 500 meter resolution	6/30/07
3. Develop quality control neural network encompassing Taiwan QC training sets	9/30/07
4. Implement radar calibration analysis tool using dual polarization radar	11/30/07
5. Quarterly progress report & annual review	3/31/07, 6/30/07 9/30/07, 11/30/07

Task #2 - Continuing Interaction on Earlier Cooperative Projects

Several earlier cooperative tasks have been completed. Technology has been transferred successfully and is beginning to be used operationally at CWB. NOAA/ESRL/GSD's development activities in these areas continue, and further CWB-NOAA/ESRL/GSD interaction is important to keep CWB staff up-to-date on current developments. This task will allow continuing interaction at an appropriate level, including new software releases of the forecast information system including the AWIPS/D2D (OB7), radar display using D2D to replace POP, dual head display support, advanced ALPS training by NOAA/ESRL/GSD, AFPS text formatter technical support, and Internet-based forecast workstation (FX-C) with advanced drawing capability with touch screen support, NOAA data support, visitors training, exchange of visits, copying papers and reports, and e-mail interaction.

The following summarizes the schedule and resources required for Task #2:

Performance Period:	29.4 CWB/NOAA/ESRL/GSD	%

Deliverables:

1. Dual-head display support	3/31/07
2. Relevant documents, reports and	(as needed)

electronic information

3. AWIPS upgrade software (OB7) and support 11/30/07

4. Advanced ALPS workstation training 11/30/07
5. AFPS text formatter evaluation support 11/30/07

6. FX-C software with enhanced drawing capability (touchscreen application) 11/30/07

7. NOAAPORT data feed support 11/30/07

8. Visitors support including necessary training and travel 11/30/07

3.0 - Schedule

Tasks Functions	Milestones
1. Provide initial STMAS 3DVAR system (from NOAA/ESRL/GSD)	12/07
2. Provide improved HRQ2 QC system (500m resolution), QC neural network and radar calibration tool (from NSSL)	12/07
3. Provide technical support and software upgrade of AWIPS, ALPS, AFPS text formatter evaluation, FX-C, NOAAPORT data transmission relevant document and technical support on WINS II with AWIPS functions (from NOAA/ESRL/GSD)	12/07

Schedule by Month

TASKS	1/1	2/1	3/1	4/1	5/1	6/1	7/1	8/1	9/1	10/1	11/1	12/1
Task 1 (GSD)												
STMAS3DVAR data Assimilation (on-line version)	x	x	x	x	x	x	x	x	x	x	x	x
Add radar data and polar orbiting satellite data into STMAS	x	x	x	x	x	x	x	x	x	x	x	x
Provide ensemble based error statistics	x	x	x	x	x	x	x	x	x	x	x	x
GSI software upgrade	x	x	x	x	x	x	x	x	x	x	x	x
IPW computed from CWB GPS-Met network	x	x	x	x	x	x	x	x	x	x	x	x
Task 1 (NSSL)												
Define HRQ2 components	x	x	x									
HRQ2 (500m) software	x	x	x	x	x	x						
Develop QC neural network	x	x	x	x	x	x	x	x	x			
Implement radar calibration tool	x	x	x	x	x	x	x	x	x	x	x	x
Verification and assessment of application performance	x	x	x	x	x	x	x	x	x	x	x	x
Task 2 (interaction on earlier projects)												
Provide relevant documents A and information	x	x	x	x	x	x	x	x	x	x	x	x
AWIPS upgrade software, AWIPS radar display technical support, AWIPS dual-head hardware support ALPS training	x	x	x	x	x	x	x	x	x	x	x	x
FX-C software with enhanced capabilities using touch screen	x	x	x	x	x	x	x	x	x	x	x	x
NOAAPORT data support												
AFPS text formatter evaluation support	x	x	x	x	x	x	x	x	x	x	x	x
Support CWB visitors		x	x	x	x	x	x	x	x	x	x	x

4.0 - Budget

The following are the estimated costs for Implementing Arrangement #19

Tasks	Personnel	Travel/Training	Total
Task #1 (GSD)	$ 285,000	$ 15,000	$ 300,000
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(NSSL)			
Task #2 (GSD)	$ 230,000	$ 20,000	$ 250,000
Total	$ 800,000	$ 50,000	$ 850,000

As stated in Implementing Arrangement #19, the funds available from TECRO to support the tasks, traveling and meeting expenses described in this Statement of Work, will be a total of US$ 850,000. TECRO agrees that US$ 500,000 will be provided by its designated representative CWB, US$ 250,000 by the Water Resources Agency (WRA) on behalf of CWB and US$ 100,000 by the Soil and Water Conservation Bureau (SWCB) on behalf of CWB. All budget figures are estimates. Actual amounts will be accrued for purposes of fulfilling the financial arrangements described in the Implementing Arrangement, in accordance with the terms of the Agreement.

All programs within the Global Systems Division (GSD) use the same budget procedures, whether they are base-funded programs or externally-funded programs. Beginning in FY91, a facility charge has been applied to all programs to cover management and administrative costs as well as the use of the NOAA/ESRL/GSD facility and all associated equipment and data.

NOAA/ESRL/GSD staff time is charged at the employee's salary plus the normal NOAA benefit, leave, and overhead charges. NOAA/ESRL/GSD professional staff people are primarily in the civil service grade scales of GS-11 to GS-14. Contract staff is in equivalent categories.

5.0 - CWB Joint Team Assignments at NOAA/ESRL/GSD

Several tasks encourage CWB staff in residence at NOAA/ESRL/GSD. The primary effort of CWB staff at NOAA/ESRL/GSD during the Implementing Arrangement #19 period will be directed toward developing the HRQ2 task. It is important that CWB staff be available to work at NOAA/ESRL/GSD facilities during the period. Specific assignments will be made to most efficiently use the available personnel resources. Assignments for the CWB staff members would be as follows:

- Development of a high-resolution QPE and QPF system for the Taiwan area (at NOAA/ESRL/GSD) and setup of AFPS text formatter environment.