NGAO System Design Phase: Work Scope Planning Sheet

WBS Element Title: **Agreeement Between Tomography Codes**
WBS Element Number: **3.1.1.2.1**
Work Package Lead: Donald Gavel
Work Package Participants: Ralf Flicker, Chris Neyman

1. Work Scope

WBS Dictionary Entry: The dictionary definition from the System Design (SD) Systems Engineering Management Plan (SEMP).
"Understand the differences between tomography codes in use at WMKO and UCSC, modify the codes as appropriate and document the result that should be used."

Requirements: Including any additional requirements, specifications, or instructions necessary to completely but concisely define the scope of work, including corrections to the dictionary definition. Be clear, where potential confusion might occur, about what will not be covered.
Compare the tomography algorithms for consistency amongst the 3 codes: Ralf Flicker's code, Brent Ellerbroek's LAOS/TAOS, and Don Gavel's TomographySphericalWave. Considers only the tomography error contributor to error budgets. Does not include modeling of wavefront sensors, deformable mirrors, or control systems.

2. Inputs:

List key assumptions that are used as starting points for this WBS element. Reference the source of the assumptions (e.g. reports, journal articles, etc.) and include a list of other NGAO WBS elements (full name and WBS #) that provide results or conclusions used as starting points for this WBS element.

- Method of LAOS/TAOS is documented in: Ellerbroek, B.L., "Efficient computation of minimum-variance wavefront reconstructors with sparse matrix techniques," JOSA-A, 19, 9, Sept., 2002, 1803-1816.
- Ralf Flicker's presentation to the EC on Nov. 14, 2006, "NGAO System Design Phase Trade study report 3.1.2.3.3 – LGS Asterism Geometry and Size" (TS-tomo.pdf) and the accompanying report (tomo.pdf).
- Method of TomographySphericalWave is documented in: Gavel, D.T., "Tomography for multiconjugate adaptive optics systems using laser guide stars," SPIE Astronomical Telescopes and Instrumentation, Vol. 5490, Glasgow, Scotland, June, 2004.

3. Products:

List all products to be produced by this WBS element. Examples include graphs, images, software, spreadsheets, simulation codes, and reports. A draft table of contents for the report should be included.

Report

1. **Introduction**

   1.1 Description of each code's **mathematical methods** – emphasize that the solution should be the same, only the solution technique differs, thus any discrepancy in solution indicates a coding error in one or both codes or a difference in implementation that introduces approximation errors, assuming the inputs are identical.

   1.2. Description and quantification of the **discrepancies expected due to different approximations** in the modeling. –E.g. Ralf Flicker's code uses a low resolution spatial domain approximation; any of the codes may use ray instead of

Fresnel propagation through the atmosphere; each code may use different (and possibly dubious) methods to generate random Kolmogorov screens.

2. Summary of **tomography results to date**. – use tables to show the tomography error prediction results for baseline cases run so far. Discuss error bars in light of approximation discrepancies.

3. Results from the **test cases** –(see below) noise-free "phantom," just measurement noise, noise-free: one guidestar, 3-guidestar, 5-guidestar

4. **Further results and conclusions** –Depending on the outcome of tests, we may either (1) identity and fix bugs in one or more codes, (2) determine that approximations in the implementation methods are a dominant source of discrepancy, then, depending on the magnitude of these discrepancies we will need to asses whether further more refined code development is needed –note that additional code development is *not* within the scope of this task. If code development is needed, an additional task will need to be integrated into the project plan's WBS–, or (3) certify codes for the classes of problems where we have deemed that errors are tolerable – the EC has recommended that "tolerable" is defined as 30 nm rms.

4. Methodology:

Outline your proposed procedure for meeting the goals of the WBS element. Describe your methodology in sufficient detail that engineers and scientist with similar background can understand your plans and would be able to verify the results.

Summarize runs that have been done so far - list the parametric assumptions and the results.

• Re-do the case where they significantly disagree, this time carefully making sure our parameter inputs are in fact the same (we were in somewhat of a rush during the proposal week).

• Run tests that quantify code behavior with respect to individual assumptions/inputs, for example:

- Do a noise-free "phatom" case, that is, using a unit aberration at some altitude and verifying that the codes produce identical results, which would be a reconstruction of the unit aberration plus explainable artifacts.
- Model the response to just measurement noise, no aberrations, and make sure codes produce the right variance in the solution
- Test solutions with one guidestar, first at infinity, then at LGS altitude
- Test solutions with three guidestars on a triangle. Check results vs angular separation.
- and so on - When we compare codes, I suggest we use identical atmosphere realization in each case, at least early on, so that we can rule out statistical variation as a source of discrepancy.

5. **Estimate of effort:**

Estimate the number of hours of work required to complete the WBS element. Compare this estimate to the one given in the SEMP.

I would estimate this will take ~60 hours: 40 hours of Don Gavel, and 20 hours of Chris Neyman and Ralf Flicker. The SEMP shows 40 man-hours assigned to this task. Should we conclude that additional code development is necessary, that additional effort would be beyond the scope of this task.

6. Approvals:

Control	Name	Date
Authored by:	**Don Gavel**	**10/01/06**
Approved by:	**3.1.1.1 Lead** **Chris Neyman**	
	NGAO EC Chair **Peter Wizinowich**	