1 PROJECT PLANS FOR NEXT YEAR

1.1 Summarize the Project Plan

By the end of Year 1, we will have accomplished the first two of our three research objectives: simulating galactic outflows with supersonic velocities, and quantifying the importance of radiative cooling for the multiphase structure seen in those outflows. Our original proposal specified a single research objective for Year 2: to determine the mass and energy coupling of ISM gas to supernova-driven outflows. While this objective is concise, the computational requirements to achieve it will be more demanding than those from our Year 1 simulations, largely because the resolution requirements will be greater than those for our current set of production simulations. Additional preparatory work will also be required in Semester 3 of our program, in order to calibrate a more realistic supernova feedback model than that being used in our Semester 2 simulations.

1.1.1 Research Milestones

As originally envisioned, all of the production simulations from Semester 2 were going to be quadrants of a galaxy, because the computing time required would have been too great to carry out a global simulation according to our original calculations. However, two factors have made it possible to carry out global simulations in Semester 2. First, we are able to use a more efficient hydrodynamics algorithm than the one used in our estimated time for the original proposal. Second, the simulations do not need to run as long as we initially estimated in order to set up a steady-state wind. While our original proposal specified 400 Myr of evolution, we have found that 100 Myr is sufficient to see the properties of the wind evolve on a global scale.

As a result, our original Research Milestone D: "Determine the role of full three-dimensionality on the velocity and density structure of galactic outflows" will be fulfilled by the simulations being carried out in Semester 2. Thus, we have restructured our milestone timeline somewhat, to better take advantage of the time awarded us in Year 1, and to progress through our proposed research objectives with an approach in which each builds naturally on the next. Despite this restructuring, our overall computational needs have not changed from the original proposal. Below we show the new set of Milestones for our project, along with their associated Research Objectives.

Because we have restructured the timeline somewhat, we have updated set of proposed simulations for Year 2. In Table 2, we list the simulations that will be completed in Year 1 and 2, along with the research objectives and milestones being addressed by each. Note that the total allocation request has not changed for Year 2.

1.2 Developmental Work

RM.E: Discrete supernova feedback models. We will implement and test two or more supernovae feedback models. The first model will input stochastic energy sources in 10pc Œ 10pc regions with a spatial sampling following the expected star formation rate density in the disk and a time sampling appropriate of averages over the lifetimes and initial mass function of massive stars in stellar clusters. Given that these supernova-heated regions will marginally resolve the size of the supernovae remnants as they enter the momentum-conserving phase, we will use the local density around the supernovae to estimate any missing momentum deposition and add that as a radially-diverging kinetic feedback. A second model will combine a smooth volumetric heating of the disk gas from a time-averaged supernovae rate with stochastic momentum feedback from star formation [40], which is expected to have a similar net effect. Given that the disk gas will be allowed to cool radiatively, heating from supernovae directly or secondary heating from supernova-driven turbulence will be required to maintain the observed disk

Table 1: Updated Research Milestones

Milestone		**Objective**
	Year 1, Semester 1	
RM.A	Create and test initial conditions for galactic disk simulations.	RO.A
RM.B	Implement and calibrate feedback model for driving galactic outflows.	RO.A
	Year 1, Semester 2	
RM.C	Model the multiphase structure and radiative cooling of galactic outflows on $\sim$ 10kpc scales.	RO.A, RO.B
RM.D	Determine the role of full three-dimensionality on the velocity and density structure of galactic outflows.	RO.A, RO.B
	Year 2, Semester 1	
RM.E	Implement and calibrate discrete supernova feedback model for driving galactic outflows	RO.A, RO.B
RM.F	Model the multiphase structure and radiative cooling of galactic outflows on $\sim$ 10kpc scales, including driving by discrete supernovae.	
	Year 2, Semester 2	
RM.G	Simulate galactic outflows at large dynamic range to generate *ab initio* $\sim$ 10kpc-scale winds from $\sim$pc-scale supernovae bubbles.	RO.A, RO.B, RO.C

thickness of M82. We will perform a series of resolution studies (RS.B) focused on the disk to verify the implementation of each feedback prescription, calibrate its efficiency to drive galactic winds, and develop yet further prescriptions if they prove unsuccessful. We have extensive experience implementing ISM and feedback models [62] that are widely used in galaxy simulations, and correspondingly this phase of the program poses little risk to our research objectives.

1.3 New Code Applications (where relevant)

We do not plan to use any new codes in Year 2. We will continue to update and improve our primary hydrodynamics code, *Cholla*, used to carry out all of the described simulations.

Table 2: Research Simulations

Simulation Type and Details		**Objective / Milestone**	**Resolution**	**Titan Nodes**	**Titan Core Hours**
Semester 1: 2M core hours					
RS.A	Initial Conditions Test Simulations	RO.A	$N = 1024^3$	512	0.5M
RS.B	Feedback Model Calibration Simulations	RO.A	$N = 1024^2 \times 2048$	1024	1.5M
Semester 2: 44M core hours					
RS.C	Adiabatic Wind Simulation	RO.A, RO.B	$N = 2048^2 \times 4096$	8192	11M
RS.D	3 Radiative Wind Simulations	RO.A, RO.B	$N = 2048^2 \times 4096$	8192	33M
Semester 3: 22M core hours					
RS.F	2 Radiative Simulations with discrete SN feedback	RO.A, RO.B, RO.C	$N = 2048^2 \times 4096$	8192	36M
Semester 4: 32M core hours					
RS.G	High-Res Radiative Simulation	RO.A, RO.B, RO.C	$N = 4096^3$	16,384	32M
	Core Hour Budget for Analysis and Data Manipulation				5M
Two-Year Program Total Titan Core Hour Request:					**104M**