NSF Midscale Research Infrastructure
Project Status Report

DarkSide Mid-scale RI-1 NSF award PHY-2131857	
Lead Institution: Princeton University	**Principal Investigator**: Cristiano Galbiati
Project Manager: Marzio Nessi, LNGS	**NSF Cognizant PO**: Darren Grant

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I. Glossary

Table 7-1. Earned Value Calculations Summary Table

Earned Value Analysis					
Abbreviation	**Name**	**Lexicon Definition**	**How Used**	**Equation**	**Interpretation of Result**
PV	Planned Value	The authorized budget assigned to scheduled work.	The value of the work planned to be completed to a point in time, usually the data date, or project completion.		
EV	Earned Value	The measure of work performed expressed in terms of the budget authorized for that work.	The planned value of all the work completed (earned) to a point in time, usually the data date, without reference to actual costs.	EV = sum of the planned value of completed work	
AC	Actual Cost	The realized cost incurred for the work performed on an activity during a specific time period.	The actual cost of all the work completed to a point in time, usually the data date.		
BAC	Budget at Completion	The sum of all budgets established for the work to be performed.	The value of total planned work, the project cost baseline.		
CV	Cost Variance	The amount of budget deficit or surplus at a given point in time, expressed as the difference between the earned value and the actual cost.	The difference between the value of work completed to a point in time, usually the data date, and the actual costs to the same point in time.	CV = EV – AC	Positive = Under planned cost Neutral = On planned cost Negative = Over planned cost
SV	Schedule Variance	The amount by which the project is ahead or behind the planned delivery date, at a given point in time, expressed as the difference between the earned value and the planned value.	The difference between the work completed to a point in time, usually the data date, and the work planned to be completed to the same point in time.	SV = EV – PV	Positive = Ahead of Schedule Neutral = On schedule Negative = Behind Schedule
VAC	Variance at Completion	A projection of the amount of budget deficit or surplus, expressed as the difference between the budget at completion and the estimate at completion.	The estimated difference in cost at the completion of the project.	VAC = BAC – EAC	Positive = Under planned cost Neutral = On planned cost Negative = Over planned cost
CPI	Cost Performance Index	A measure of the cost efficiency of budgeted resources expressed as the ratio of earned value to actual cost.	A CPI of 1.0 means the project is exactly on budget, that the work actually done so far is exactly the same as the cost so far. Other values show the percentage of how much costs are over or under the budgeted amount for work accomplished.	CPI = EV/AC	Greater than 1.0 = Under planned cost Exactly 1.0 = On planned cost Less than 1.0 = Over planned cost
SPI	Schedule Performance Index	A measure of schedule efficiency expressed as the ratio of earned value to planned value.	An SPI of 1.0 means that the project is exactly on schedule, that the work actually done so far is exactly the same as the work planned to be done so far. Other values show the percentage of how much costs are over or under the budgeted amount for work planned.	SPI = EV/PV	Greater than 1.0 = Ahead of schedule Exactly 1.0 = On schedule Less than 1.0 = Behind schedule
EAC	Estimate At Completion	The expected total cost of completing all work expressed as the sum of the actual cost to date and the estimate to complete.	If the CPI is expected to be the same for the remainder of the project, EAC can be calculated using: If future work will be accomplished at the planned rate, use: If the initial plan is no longer valid, use: If both the CPI and SPI influence the remaining work, use:	EAC = BAC/CPI EAC = AC + BAC – EV EAC = AC + Bottom-up ETC EAC = AC + [(BAC – EV)/(CPI x SPI)]	
ETC	Estimate to Complete	The expected cost to finish all the remaining project work.	Assuming work is proceeding on plan, the cost of completing the remaining authorized work can be calculated using: Reestimate the remaining work from the bottom up.	ETC = EAC – AC ETC = Reestimate	
TCPI	To Complete Performance Index	A measure of the cost performance that must be achieved with the remaining resources in order to meet a specified management goal, expressed as the ratio of the cost to finish the outstanding work to the budget available.	The efficiency that must be maintained in order to complete on plan. The efficiency that must be maintained in order to complete the current EAC.	TCPI = (BAC – EV)/(BAC – AC) TCPI = (BAC – EV)/(EAC – AC)	Greater than 1.0 = Harder to complete Exactly 1.0 = Same to complete Less than 1.0 = Easier to complete Greater than 1.0 = Harder to complete Exactly 1.0 = Same to complete Less than 1.0 = Easier to complete

Figure I.A: Earned value calculations summary table (from PMBOK [*A Guide to the Project Management Body of Knowledge*, Project Management Institute, Inc., Fifth Edition (2013)]).

The following definitions are extracted and adapted from PMBOK [*A Guide to the Project Management Body of Knowledge*, Project Management Institute, Inc., Fifth Edition (2013)].

Planned Value (PV)
Planned value (PV) is the authorized budget assigned to scheduled work. It is the authorized budget planned for the work to be accomplished for an activity or work breakdown structure component, not including management reserve. This budget is allocated by phase over the life of the project, but at a given moment, planned value defines the physical work that should have been accomplished. The total of the PV is sometimes referred to as the performance measurement baseline (PMB).

Budget at Completion (BAC)
The total planned value for the project is also known as budget at completion (BAC).

Earned Value (EV)
Earned value (EV) is a measure of work performed expressed in terms of the budget authorized for that work. It is the budget associated with the authorized work that has been completed. The EV being measured needs to be related to the PMB, and the EV measured cannot be greater than the authorized PV budget for a component. The EV is often used to calculate the percent complete of a project. Progress measurement criteria should be established for each WBS component to measure work in progress. Project managers monitor EV, both incrementally to determine current status and cumulatively to determine the long-term performance trends.

Actual/Obligated Cost (AC)
Actual/obligated cost (AC) is the realized cost incurred for the work performed on an activity during a specific time period or already committed to a third party supplier through a binding purchase order. It is the total cost incurred in accomplishing the work that the EV measured. The AC needs to correspond in definition to what was budgeted in the PV and measured in the EV (e.g., direct hours only, direct costs only, or all costs including indirect costs). The AC will have no upper limit; whatever is spent to achieve the EV will be measured.

Schedule Performance Index (SPI)
The schedule performance index (SPI) is a measure of schedule efficiency expressed as the ratio of earned value to planned value. It measures how efficiently the project team is using its time. It is sometimes used in conjunction with the cost performance index (CPI) to forecast the final project completion estimates. An SPI value less than 1.0 indicates less work was completed than was planned. An SPI greater than 1.0 indicates that more work was completed than was planned. Since the SPI measures all project work, the performance on the critical path also needs to be analyzed to determine whether the project will finish ahead of or behind its planned finish date. The SPI is equal to the ratio of the EV to the PV.
`Equation: SPI = EV / PV.`

Cost Performance Index (CPI)
The cost performance index (CPI) is a measure of the cost efficiency of budgeted resources, expressed as a ratio of earned value to actual cost. It is considered the most critical EVM metric and measures the cost efficiency for the work completed. A CPI value of less than 1.0 indicates a cost overrun for work completed. A CPI value greater than 1.0 indicates a cost underrun of performance to date. The CPI is equal to the ratio of the EV to the AC. The indices are useful

for determining project status and providing a basis for estimating project cost and schedule outcome.

Equation: CPI = EV / AC.

Estimate at Completion Forecast for Estimate to Complete Work Performed at the Budgeted Rate (EAC)

This EAC method accepts the actual project performance to date (whether favorable or unfavorable) as represented by the actual costs, and predicts that all future ETC work will be accomplished at the budgeted rate. When actual performance is unfavorable, the assumption that future performance will improve should be accepted only when supported by project risk analysis.

Equation: EAC = AC + (BAC – EV).

Estimate at Completion Forecast for Estimate to Complete Work Performed at the Budgeted Rate (EAC-C-PI)

This method assumes what the project has experienced to date can be expected to continue in the future. The ETC work is assumed to be performed at the same cumulative cost performance index (CPI) as that incurred by the project to date.

Equation: EAC-C-PI = BAC / CPI.

Estimate at Completion Forecast for Estimate to Complete Work Considering both SPI and CPI Factors (EAC-C/S-PI)

In this forecast, the ETC work will be performed at an efficiency rate that considers both the cost and schedule performance indices. This method is most useful when the project schedule is a factor impacting the ETC effort. Variations of this method weight the CPI and SPI at different values (e.g., 80/20, 50/50, or some other ratio) according to the project manager's judgment.

Equation: EAC-C/S-PI = AC + [(BAC – EV) / (CPI × SPI)].

Estimate to Complete (ETC)

Estimate to complete (ETC) is the expected cost to finish all the remaining project work. Assuming work is proceeding on plan, the cost of completing the remaining authorized work can be calculated using the difference between EAC and AC. If the work is proceeding with a CPI substantially different from unity, the trend value of ETC is the the difference between EAC and AC divided by CPI.

Equations: ETC-Simple = EAC - AC; ETC-Trend = (EAC – AC) / CPI.

To-Complete Performance Index (TCPI)

The to-complete performance index (TCPI) is a measure of the cost performance that is required to be achieved with the remaining resources in order to meet a specified management goal, expressed as the ratio of the cost to finish the outstanding work to the remaining budget. TCPI is the calculated cost performance index that is achieved on the remaining work to meet a specified management goal, such as the BAC or the EAC. If it becomes obvious that the BAC is no longer viable, the project manager should consider the forecasted EAC. Once approved, the EAC may replace the BAC in the TCPI calculation.

Equation BAC: (BAC – EV) / (BAC – AC).

Schedule Variance (SV)

Schedule variance (SV) is a measure of schedule performance expressed as the difference between the earned value and the planned value. It is the amount by which the project is ahead or behind the planned delivery date, at a given point in time. It is a measure of schedule performance on a project. It is equal to the earned value (EV) minus the planned value (PV). The EVM schedule variance is a useful metric in that it can indicate when a project is falling behind or is ahead of its baseline schedule. The EVM schedule variance will ultimately equal zero when the project is completed because all of the planned values will have been earned. Schedule variance is best used in conjunction with critical path methodology (CPM) scheduling and risk management.

Equation: SV = EV – PV.

Cost Variance (CV)

Cost variance (CV) is the amount of budget deficit or surplus at a given point in time, expressed as the difference between earned value and the actual cost. It is a measure of cost performance on a project. It is equal to the earned value (EV) minus the actual cost (AC). The cost variance at the end of the project will be the difference between the budget at completion (BAC) and the actual amount spent. The CV is particularly critical because it indicates the relationship of physical performance to the costs spent. Negative CV is often difficult for the project to recover.

Equation: CV= EV – AC.

Variance at Completion (VAC)

Variance at completion (VAC) is projection of the amount of budget deficit or surplus, expressed as the difference between the budget at completion and the estimate at completion. It consists of the estimated difference in cost at the completion of the project.

Equation: VAC = BAC – EAC.

Work Completed (WC)

Work completed is the weighted average for the completion of all completed tasks, where the completed fraction of each task (WC_i : percentage of work done for task *i*) is weighted with its budget (BAC_i). The work completed fraction can be calculated globally or at each WBS level or for the whole project.

Equation: $WC = \sum_i (WC_i \times BAC_i) / BAC$.

II. Summary of Project Budget and Schedule Status

The project budget and schedule are in good condition. See the current award summary information in Table II.B, the current earned value metrics in Table II.B, and the progress of work performed (EV), actual/obligated cost (AC), and baseline plan (PV) vs. time in Figure II.C.

Award	**Award Start** (mm/dd/yyyy)	**Award End** (mm/dd/yyyy)	**Total Project Cost (TPC)** BAC + Contingency
	09/01/2022	08/31/2025	$11.711M
Project Budget	**BAC** Budget At Completion	**ETC** Estimate To Complete	**Remaining Funds**
	$9.035M	$7.703M	$7.988M
Budget Contingency	**Awarded**	**Remaining**	
	$2.675M	$2.675M	
Performance Indicators	**WC** Work Completed	**CPI** Cost Perf. Index	**SPI** Schedule Perf. Index
	15.1%	1.27	1.73

Table II.A: Award summary information.

Earned Value Metrics Q2-2023		
BAC	$9,034,819	
PV	$768,350	
EV	$1,332,164	
AC	$1,046,563	
SPI	173%	EV / PV
CPI	127%	EV / AC
EAC	$8,749,218	EAC = AC + (BAC – EV)
EAC-C-PI	$7,097,855	BAC / CPI
EAC-C/S-PI	$4,536,757	AC + [(BAC – EV) / (CPI × SPI)]
ETC-Simple	$7,702,655	EAC – AC
ETC-Trend	$6,051,292	(EAC – AC) / CPI
SV	$563,814	EV – PV
CV	$285,601	EV – AC
VAC	$285,601	BAC – EAC
WC	15.1%	$\sum_i (WC_i \times BAC_i)$ / BAC
Remaining Funds	$7,988,256	BAC – AC

Table II.B: Earned value metrics for partial Q2-2023 (through May 2023).

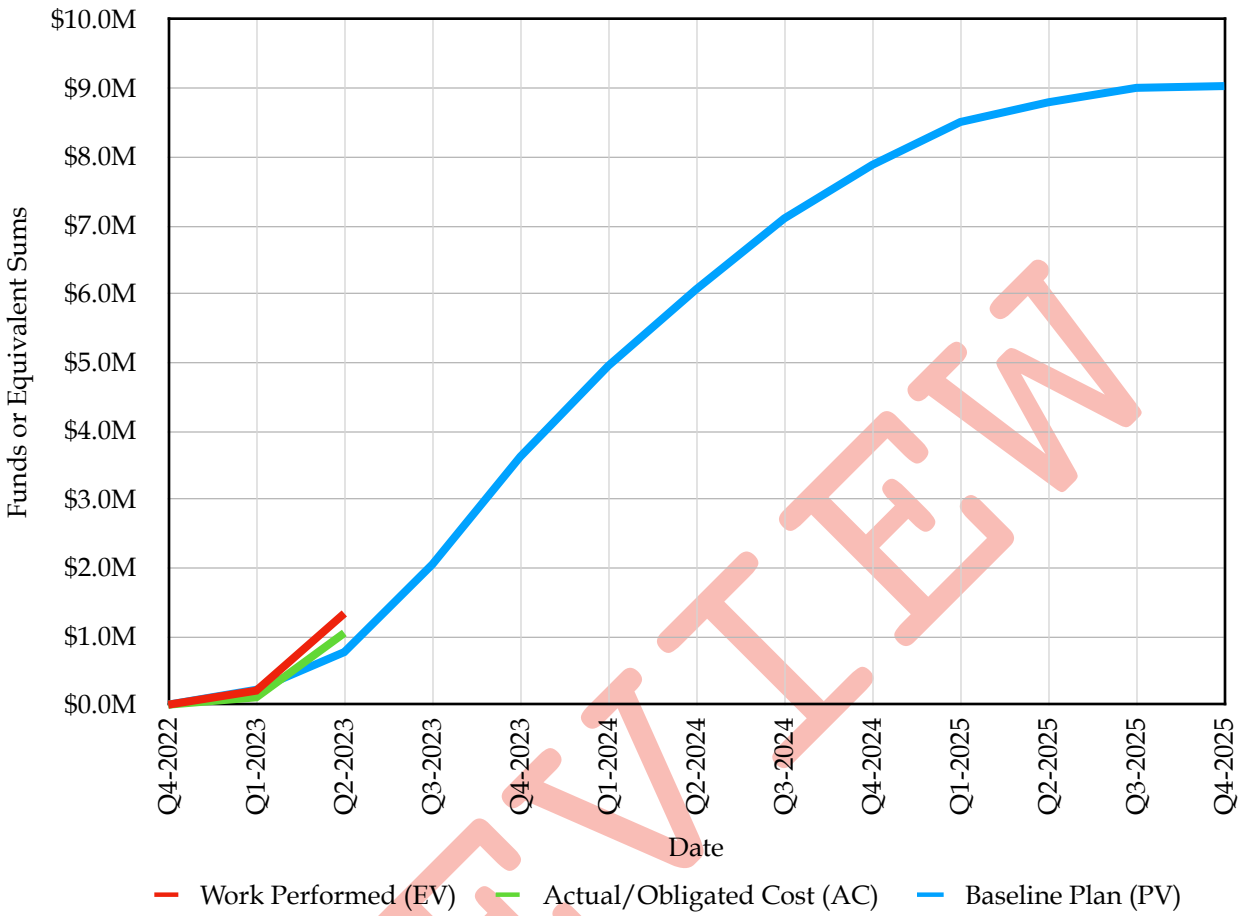

Figure II.C: Work performed (EV), actual/obligated cost (AC), and baseline plan (PV) vs. time.

III. Milestones

The DS-20k schedule uses a system of tiered milestones associated with key deliverables by each partner agency.

Table III.A lists the highest level Tier 1 milestones associated with the key deliverables (a.k.a. KPP, key performance parameters) of the U.S. NSF Mid-scale RI-1 DarkSide award, and the next-highest level Tier 2 completion milestones leading to each Tier 1.

Figure III.B shows the forecast (and accomplished) date as function of time for the Tier 1 and 2 milestones owned by the U.S. Institutions and within the scope of the NSF Midscale RI-1 DarkSide cooperative agreement. (Note: solid lines with black-filled romboids identify milestones already completed; dashed line identify milestones not yet completed, whose monitoring will continue in the next editions of this document.)

One or more Tier 3 milestones lead to their related Tier 2. Tier 3 milestones mark the progress of scheduled activities. Table III.C holds Tier 3 milestones associated with activities of the U.S. NSF Mid-scale RI-1 DarkSide award. Issuing of the sub-awards is the starting milestone for scheduled activities by the sub-award recipients.

Figure III.D shows the forecast (and accomplished) date as function of time for the Tier 3 milestones owned by the U.S. Institutions and within the scope of the NSF Midscale RI-1 DarkSide cooperative agreement. (Note: solid lines with black-filled

Milestone Tier	High Level Milestones Related to NSF Mid-scale grant Deliverables	Baseline Date [mm/dd/yy]	Forecast/ Compl. Date [mm/dd/yy]
Tier 2	TPC components (field cage, reflector, wire grid) delivered to assembly locations	05/27/2025	05/27/2025
Tier 2	Outer cage assembly and PDU integration completed	03/21/2025	03/21/2025
Tier 2	Detector hanger support system delivered to LNGS	12/10/2024	12/10/2024
Tier 2	Detector feed-through flanges and chimneys delivered to LNGS	03/10/2025	03/10/2025
Tier 1	NSF Key Deliverable: LArTPC detector components, optical planes and installation fixtures delivered to LNGS	08/13/2025	08/13/2025
Tier 2	UAr base system procured, fabricated, and delivered to LNGS	10/20/2025	10/20/2025
Tier 2	UAr purification system procured, fabricated, and delivered to LNGS	04/07/2025	04/07/2025
Tier 1	NSF Key Deliverable: UAr cryogenics system components delivered to LNGS	10/20/2025	10/20/2025
Tier 2	Calibration guide tube procurements complete	01/16/2024	01/16/2024
Tier 2	Calibration deployment system delivered to LNGS	01/20/2025	01/20/2025
Tier 1	NSF Key Deliverable: Calibration System delivered to LNGS, ready for installation	01/20/2025	01/20/2025

Table III.A: Completion milestones for key deliverables (a.k.a. KPP, key performance parameters).

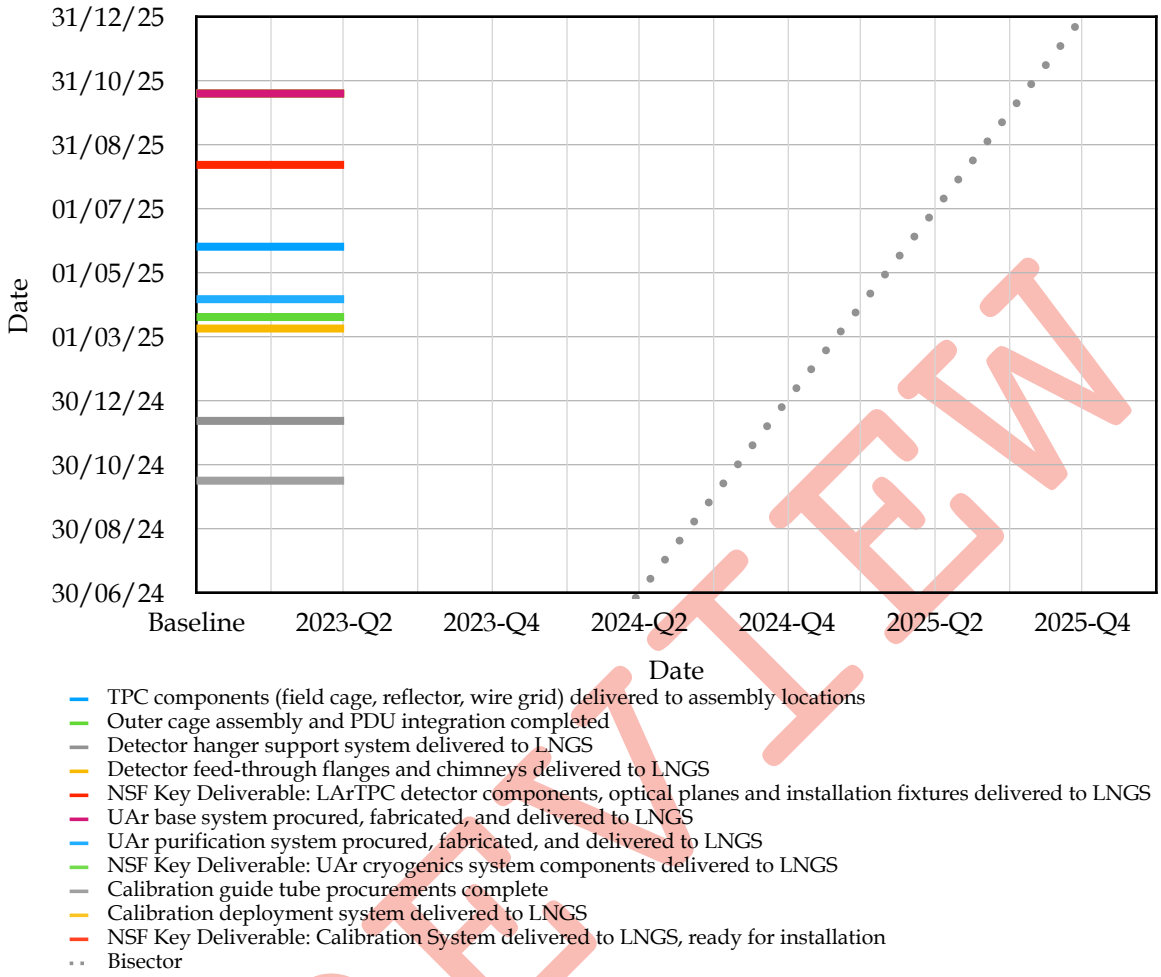

Figure III.B: Forecast (and accomplished) date as function of time for the Key Deliverables (a.k.a. KPP, Key Performance Parameters) owned by the U.S. Institutions and within the scope of the NSF Midscale RI-1 DarkSide cooperative agreement.

romboids identify milestones already completed; dashed line identify milestones not yet completed, whose monitoring will continue in the next editions of this document.)

Milestone/ Activity Description	Planned Date [mm/dd/yy]	Forecast Date [mm/dd/yy]	Act. Compl. Date [mm/dd/yy]	Variance [# of w/d]
Distribute year 1 sub-awards to US NSF PIs	1/31/23		1/31/23	0w
Procurement Readiness Review for Inner Detector Acrylic	4/12/23		5/12/23	4w
Mockup grid completed & shipped to Canada	5/10/23	9/10/23		18w
Award contracts for TPC PMMA	8/8/23		5/25/23	-10w 5d
Large deposition chamber and monitoring devices delivered to Alberta	1/10/24	1/10/24		-
Mockup TPC mechanical test completed	2/13/24	2/13/24		-
Mock TPC ready for operation	2/27/24	3/12/24		-
DSS ready for installation onto top cap	6/18/24	6/18/24		-
Acrylic components delivered	8/27/24	8/27/24		-
Outer cage delivered to LNGS	11/9/24	11/9/24		-
Calibration system US components delivered to LNGS	3/20/25	3/20/25		-
UAr radon removal system delivered to Hall C	4/7/25	4/7/25		-
Calibration sources delivered to LNGS	5/8/25	5/8/25		-
All Inner Detector components delivered to assembly location	5/27/25	5/27/25		-
UAr cryogenics delivered to Hall C	8/18/25	8/18/25		-
Calibration system installed	2/20/26	2/20/26		-

Table III.C: Tier 3 milestones.

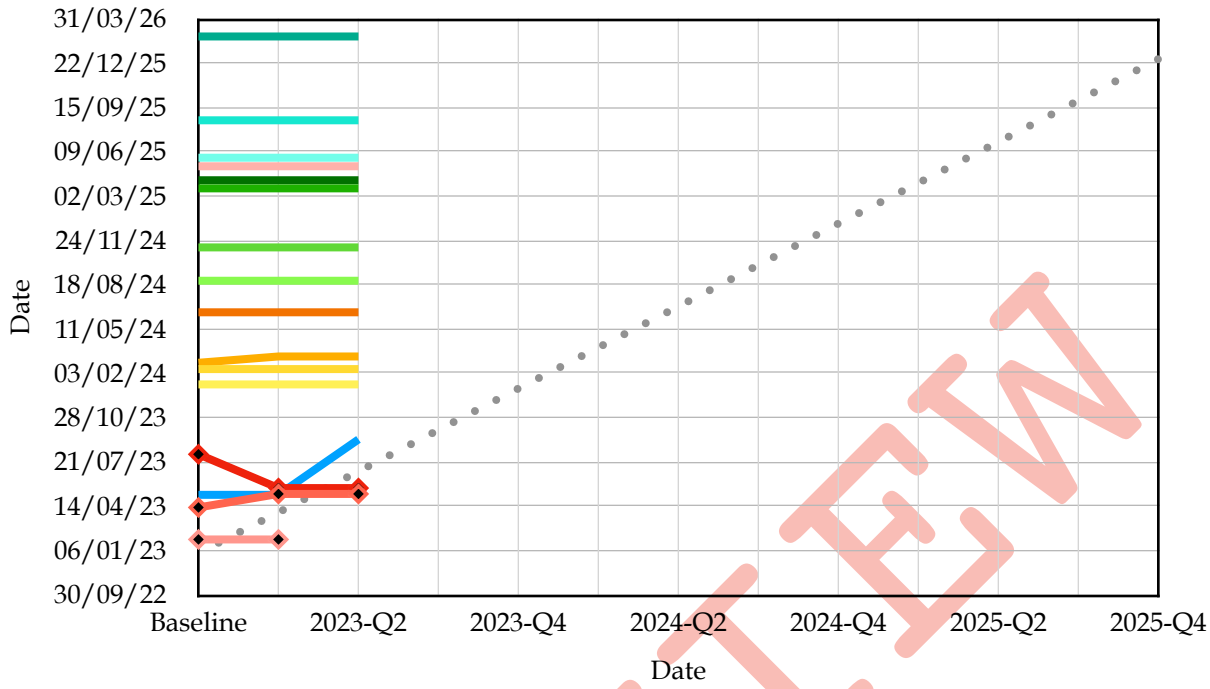

Figure III.D: Forecast (and accomplished) date as function of time for the Tier 1 milestones owned by the U.S. Institutions and within the scope of the NSF Midscale RI-1 DarkSide cooperative agreement. Legenda: solid lines with black-filled romboids identify Tier 1 milestones already completed; dashed line identify Tier 1 milestones not yet completed, whose monitoring will continue in the next editions of this document.

IV. Risks

Nothing to report

V. Change Requests and Replanning

Following the retirement of UCLA PI Dr. Hanguo Wang, the Princeton and UCLA administrations are working to terminate the Mid-scale subaward to UCLA. Specific tasks and deliverables previously assigned to UCLA are being returned under Princeton purview..

VI. Detailed Cost and Performance Data

See Table VI.A.

VII.Financial Summary and Projections

Year 1 funding providing $3.748M budget and $1.250M contingency has been received by the principal institution. $2.925M of the budget is distributed as sub-awards to the participating institutions as their portion of year 1 funding. The Project has incurred approximately $1,046K in actual/obligated costs (through May 2023).

VIII.Project Status (Technical) Progress

Technical progress is thoroughly documented in the monthly reports.

Detailed EVM Data			Cumulative [k$]				Cumulative []		
WBS	**Description**	**Institution**	**BAC**	**PV**	**EV**	**AC**	**WC**	**CPI**	**SPI**
0.01.02	Mgmt. Support NSF	Princeton	$555.1	$229.2	$158.4	$158.4	29%	1.00	0.69
1.01.02.01	UAr Base System	UCLA	$353.6	$0.0	$0.0	$0.0			
1.01.02.02	UAr Purification System	Columbia	$1,228.0	$162.8	$87.7	$21.9	6%	4.00	0.54
1.01.02.03	UAr Getter	Princeton	$487.3	$0.0	$0.0	$0.0			
1.02.02.02	ID Assembly Tools US	VTech & Will.	$1,401.9	$133.5	$585.0	$548.0	36%	1.07	4.38
1.02.04.01	ID Acrylic US	VTech & Will.	$621.2	$0.0	$368.3	$189.0	90%	1.95	N/A
1.02.04.02	S2 System	UCLA	$92.9	$0.0	$0.0	$0.0			
1.02.04.03	Outer Cage	Chicago	$717.0	$62.6	$35.8	$34.6	5.0%	1.03	0.57
1.02.04.04	HV System	UC Davis	$457.6	$3.2	$22.2	$19.6	5%	1.13	6.94
1.02.04.05	Reflectors	UC Davis	$132.2	$0.0	$0.0	$0.0			
1.02.04.06	Wire Grid	Houston	$630.5	$31.4	$0.0	$0.0	0%	N/A	0.00
1.02.05.01	ID Flanges & Chimneys	UCLA	$512.5	$0.0	$0.0	$0.0			
1.02.05.02	ID Adjustable Hangers	UCLA	$200.0	$0.0	$0.0	$0.0			
1.02.05.03	ID Integration Support	Princeton	$1,050.5	$119.6	$74.7	$75.0	8%	1.00	0.62
1.04.01.01	Calib. Deployment US	Hawaii	$384.4	$0.0	$0.0	$0.0			
1.04.02.01	Calib. Sources US	Hawaii	$137.4	$1.1	$0.0	$0.0	0%	N/A	0.00
1.09	Outreach US	Fort Lewis & PU	$210.2	$25.0	$0.0	$0.0	0%	N/A	0.00
All Sub-Systems			**$9,034.8**	**$768.4**	**$1,332.1**	**$1,046.5**	**15.1%**	**1.27**	**1.73**

Table VI.A: Detailed cost and performance data.