**Project Name:** Data Organization Techniques for Shingled Disks  
**Start Date:** April 2011

**Project Investigators:** Ethan Miller, Darrell Long, Rekha Pitchumani, Stephanie Jones, Andy Hospodar  
**Affiliates/Collaborators:** Ahmed Amer, Santa Clara University

**Description:**

“Shingled Magnetic Recording (SMR) and its follow-on, Two-Dimensional Magnetic Recording (TDMR) offer another avenue that does not place such demands on radically new media or heads but rather on the data-handling architecture and on signal processing.” Roger Wood, Hitachi GST

Shingled write recording trades the inconvenience of the inability to update in-place for a much higher data density by a using a different write technique that overlaps the currently written track with the previous track. Random reads are still possible on such devices, but writes must be done largely sequentially.

Our project has several goals. First, we want to identify techniques that can effectively utilize shingled disks to store data while providing an interface that works with existing systems, whether such an interface is block-based (as with current disks) or a different interface. Second, we want to explore new potential uses for shingled disk that leverage their inability to overwrite data in place. These uses may include archival storage, compliance storage, and designs that provide continuous data protection by default, as well as other uses.

**Research / Experimental Plan:**

We will research the benefits of shingled disks in a variety of workloads. To do this, we will first develop a shingled disk emulator, allowing us to experiment with a range of assumptions about shingled disk without the need to have real shingled disk hardware. We will then propose approaches to managing data on shingled disk, and implement and test those approaches using our emulation framework. We will quantify the benefits and drawbacks of shingled disk in terms of capacity, performance, power, and reliability, as well as other factors such as security and usability. We will also explore the use of NVRAM for metadata storage as well as the use of random-access zones for metadata.

We will work on reducing the data movement that occurs during band compaction for shingled write disks, using write heat as an indication of data that is likely to leave holes. We will also explore complementary applications such as archival storage, compliance storage leveraging encryption and non-repudiation, and other applications that may benefit from shingled disk characteristics.
**Milestones / Deliverables:**

**Previous 6 months.**
- Proposed and evaluated write-offloading to NVRAM device one and only when compaction is in progress as a technique to mitigate compaction’s performance impact on incoming writes.
- Continued work focusing on reducing long term data movement over the life of a shingled disk drive, that includes an algorithm that weights cold data to assist in picking bands for compaction, prioritizing bands that have data that is least likely to be overwritten, a two segment write buffer to separate hot and cold data during compaction, and a straightforward cooling heuristic, and compared our work against LFS’ cost-benefit policy.

**Current**
- Writing and finishing up.

**Next 6 months or Exit Plan**
- New students may pick up where Rekha and Stephanie left off, focusing on reducing the read and write amplification.

**Related Work Elsewhere:**
Carnegie Mellon University Parallel Data Lab
Data Storage Institute, Singapore, Japan; Tohoku University, Sendai, Japan; Niigata Institute of Technology, Japan; University of Manchester, Manchester, United Kingdom describe “Shingled recording for 2–3 Tbit/in2”
Hitachi GST

**Related Work within CRSS:**

NVRAM storage, long term archival storage

**Budget, Funding, Intellectual Property:**

- **Spending vs. Budget**
  - Additional CRSS Funding requests
  - Additional non-CRSS Funding
  - In-kind contributions

- **Intellectual Property**
  - IP disclosures
  - Patent filings