

# TMRC 2017

The 28<sup>th</sup> Magnetic Recording Conference

ありがとうございました  
THANK YOU

## Conference Co-Chairs

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Seagate Technology

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Tohoku Inst Technology

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Seagate Technology

Yukiko Takahashi  
National Inst. for Material Sci.

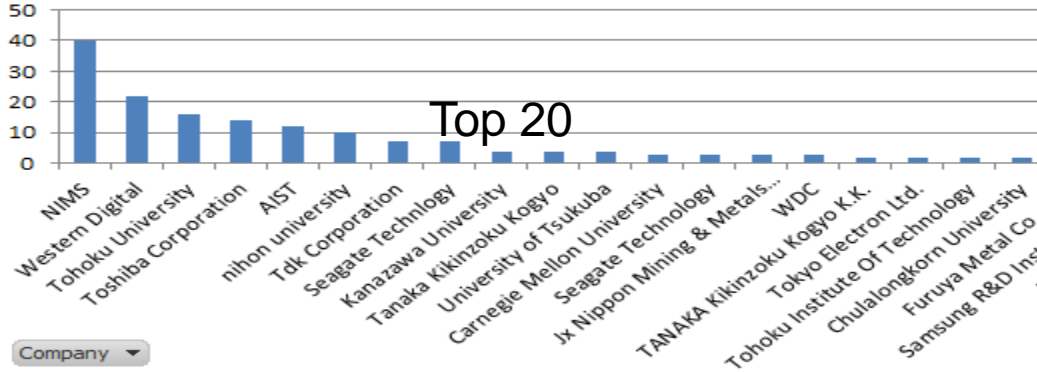
## Publicity Chair

Shin Saito  
Tohoku University

Location	August 2nd (Wed)	August 3rd (Thr)	August 4th (Fri)
Convention Hall Lobby	Registration 8:15AM	Registration 8:30AM	Registration 8:30AM
Convention Hall 200	8:50AM: Welcome		
	Session A HAMR I (Media) 9:00AM - 12:20PM	Session C MRAM I 8:50AM - 12:10PM	Session E MAMR and Related 8:50AM - 12:10PM
	Coffee Break 10:30AM - 10:50AM	Coffee Break 10:20AM - 10:40AM	Coffee Break 10:20AM - 10:40AM
Multi-purpose Hall	Lunch 12:20PM - 1:20PM	Lunch 12:10PM - 1:10PM	Lunch 12:10PM - 1:10PM
Convention Hall 200	Session B Advanced Recording Components and Systems 1:00PM - 5:10PM	Session D HAMR II (Systems) 1:10PM - 5:00PM	Session F MRAM II 1:10PM - 4:30PM
	Coffee Break 2:50PM - 3:10PM	Coffee Break 2:40PM - 3:00PM	Coffee Break 2:40PM - 3:00PM
	Session BP HAMR & Systems Contributed Posters & Invited A, B, D 5:10PM - 7:00PM	Session DP MRAM & MAMR Contributed Posters & Invited C, E, F 5:00PM - 6:40PM	4:30PM: Closing Remarks
Multi-purpose Hall			Optional NIMS and AIST tour Research Center for Magnetic and Spintronic Materials, NIMS, and Spintronics Research Center, AIST 4:45PM - 6:45PM
Convention Hall 200		Banquet 7:00PM - 9:00PM	
Multi-purpose Hall		Keynote 8:00PM - 8:30PM	



Count of Company



Row Labels	Count of Work Country
Japan	186
USA	49
Singapore	4
Thailand	3
Taiwan	3
India	3
China	2
South Korea	2
Malaysia	2
Austria	1
Cote d'Ivoire	1
Czech Republic	1
Russian Federation	1
Jamaica	1
France	1
Germany	1
Switzerland	1
(blank)	
<b>Grand Total</b>	<b>262</b>

ference (TMRC2017)



**The 28th Magnetic Recording Conference (TMRC2017)**

August 2 – 4, Tsukuba, Japan

# **Pre-TMRC 2017 Technology Survey.**

**07/20/17 and 8/2/17**

**Chris Rea**

# Survey this year 1/2

## TMRC 2017 Survey

Survey of opinions on technology intercepts for HDD and MRAM industry.

### \* 1. Describe your affiliation ?

- ☐ HDD Industry Member
- ☐ MRAM Industry Member
- ☐ Academia
- ☐ Vendor
- ☐ Other

### \* 2. What is the Maximum Areal Density Capability expected for Perpendicular/Shingled/Two dimensional - magnetic recording extensions?

### 3. What is the expected Year of Technology introduction to HDD Products ?

	2017	2018	2019	2020	2021	2022	2023	2025	2027	Never
BPM	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
HAMR	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
MAMR	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
TDMR (Multiple Readers on single track)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
HDMM(BPM+HAMR)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Survey issued in 2 waves:

- First survey:** up to 12 days before conference start.
- Second survey:** will be issued Wednesday morning of conference, and closed Friday AM
- Goal:** look at change in perspectives due to meeting.

## MRAM questions....

**4. What is the expected MRAM capacity (Megabits) per chip in 2020 ?**

128 Mb	256 Mb	512Mb	1 Gb	2 Gb	4 Gb	N/A
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**5. What is the expected NAND capacity (Gigabits) per chip in 2020?**

1000 Gb	2000 Gb	3000 Gb	5000 Gb	10,000 Gb	N/A
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

# Population of respondents 07/15/2017

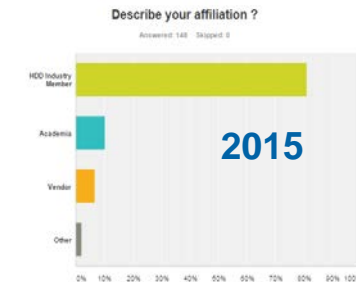
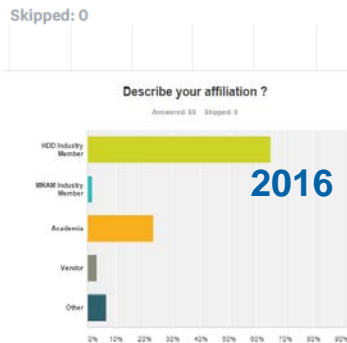
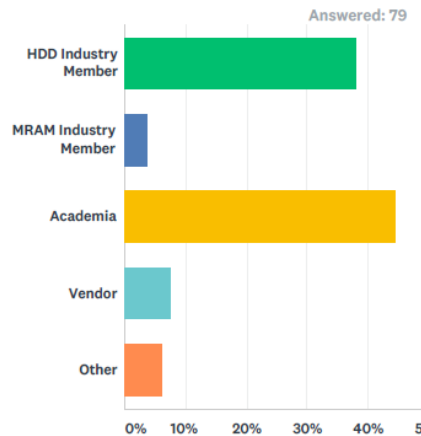
As with 2015.

Dominant responses from HDD members.

Larger fraction (44%) of academia than other years.

Can separate for analysis..

## Q1 Describe your affiliation ?

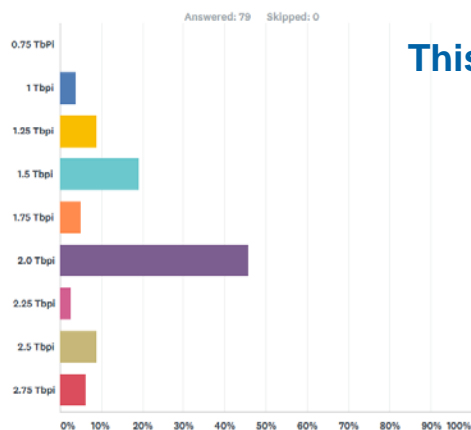


Answer Choices	Responses
HDD Industry Member	37.97% 30
MRAM Industry Member	3.80% 3
Academia	44.30% 35
Vendor	7.59% 6
Other	6.33% 5
Total	79

# Maximum ADC

- Median of 1.75 Tb/inch<sup>2</sup> +/-0.25
- A few optimistic voters for 2.5 Tb/inch<sup>2</sup>, and above.

**Q2 What is the Maximum Areal Density Capability expected for Perpendicular/Shingled/Two dimensional - magnetic recording extensions?**

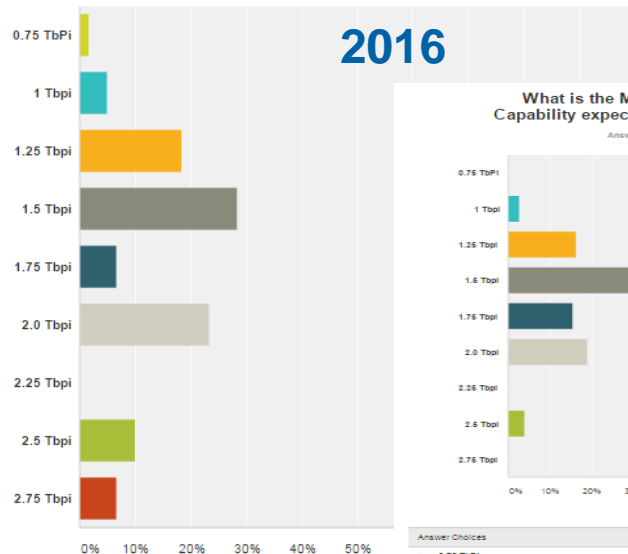


**This Survey**

Answer Choices	Responses
0.75 TbPi	0.00%
1 Tbpi	3.80%
1.25 Tbpi	8.86%
1.5 Tbpi	10.99%
1.75 Tbpi	5.06%
2.0 Tbpi	45.57%
2.25 Tbpi	2.53%
2.5 Tbpi	8.86%
2.75 Tbpi	6.33%
Total	79

**What is the Maximum Areal Density Capability expected for Perpendicular/Shingled/Two dimensional - magnetic recording extensions?**

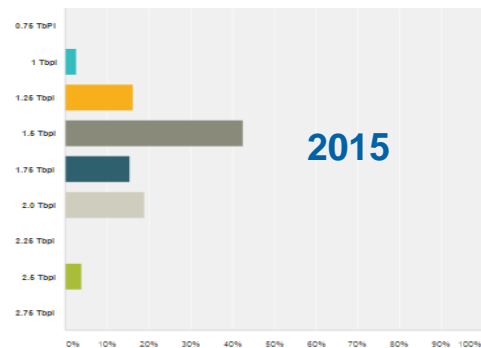
Answered: 60 Skipped: 0



Answer Choices	Response
0.75 TbPi	1.67%
1 Tbpi	5.00%
1.25 Tbpi	18.33%
1.5 Tbpi	28.33%
1.75 Tbpi	6.67%
2.0 Tbpi	23.33%
2.25 Tbpi	0.00%
2.5 Tbpi	10.00%
2.75 Tbpi	6.67%

**What is the Maximum Areal Density Capability expected for PMR/SMR/TDMR ?**

Answered: 148 Skipped: 0

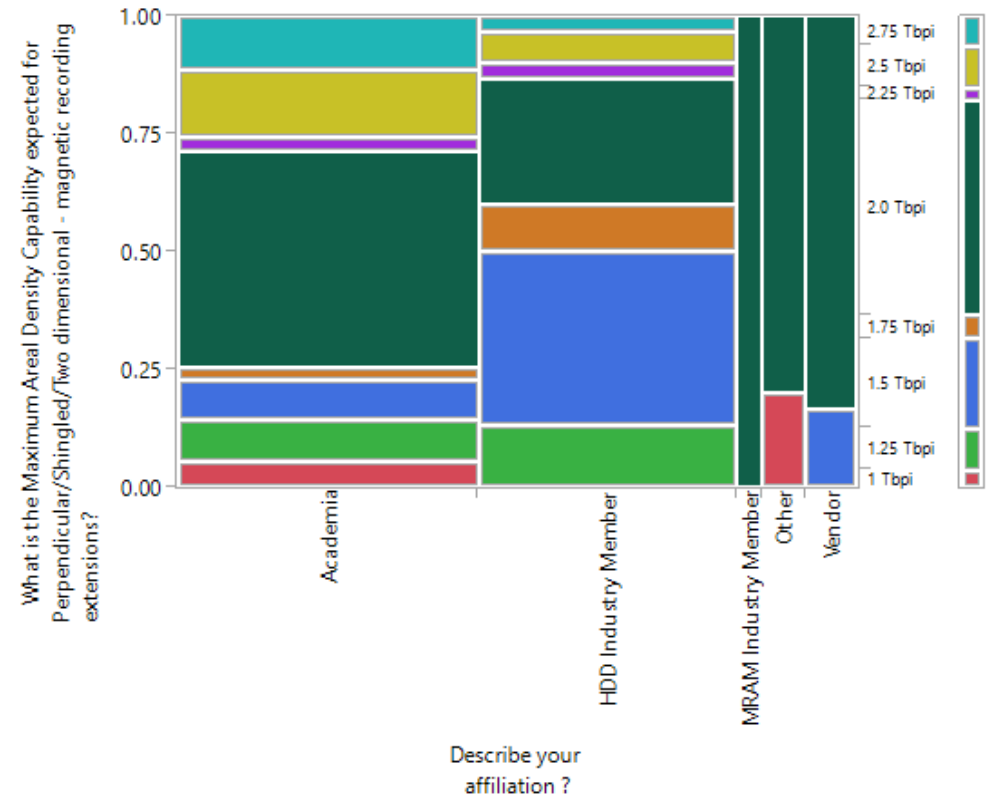


Answer Choices	Responses
0.75 TbPi	0.00%
1 Tbpi	2.70%
1.25 Tbpi	18.22%
1.5 Tbpi	42.67%
1.75 Tbpi	16.64%
2.0 Tbpi	18.82%
2.25 Tbpi	0.00%
2.5 Tbpi	4.06%
2.75 Tbpi	0.00%
Total	148

17
4
14
0
6
4

# By group

Mosaic Plot



HDD Industry favors 2T and below

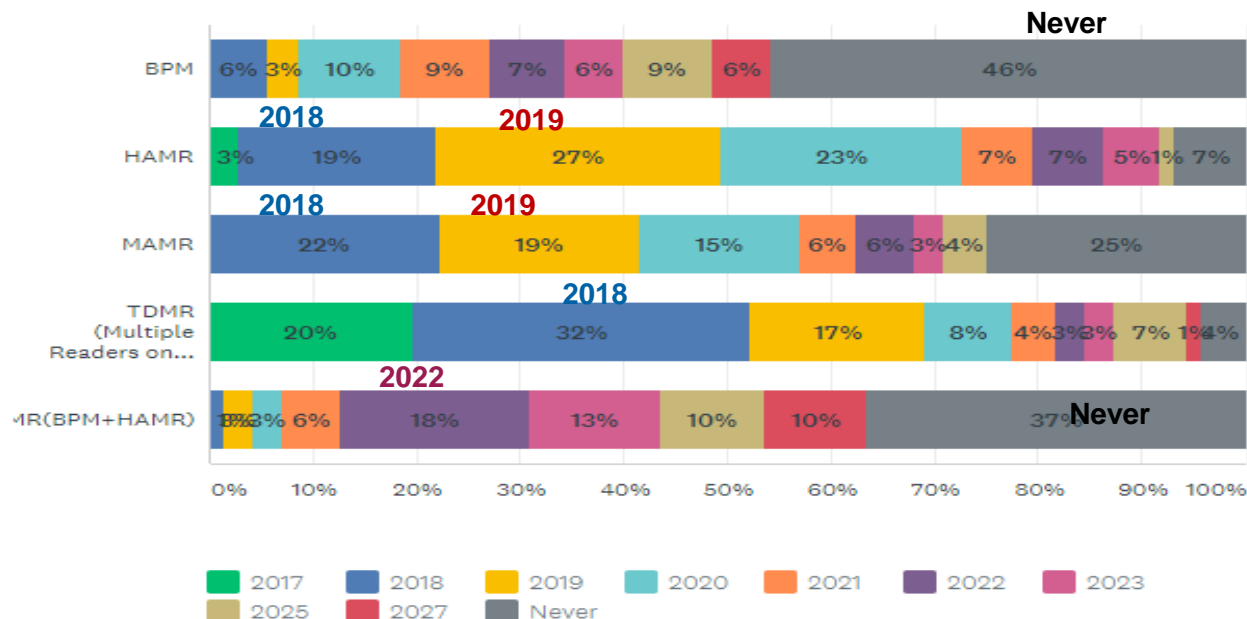
Academia and others favour 2T and above.



# Technology Survey

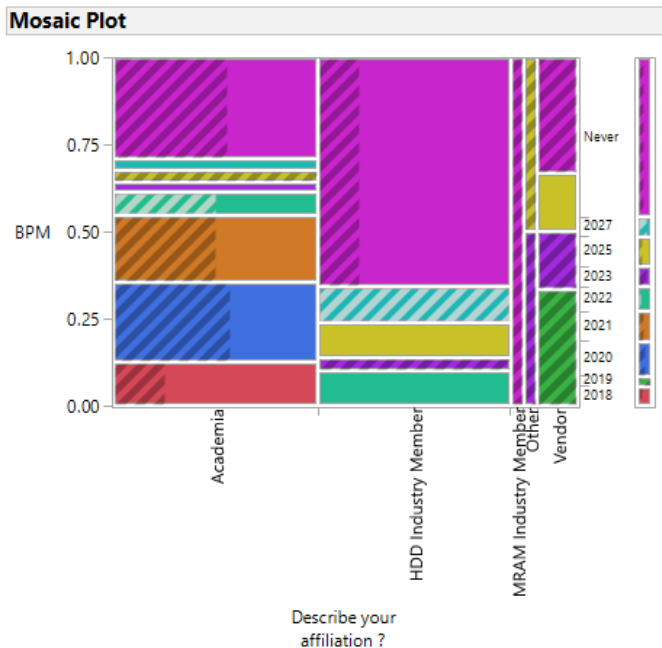
What is the expected Year of Technology introduction to HDD Products ?

Answered: 74 Skipped: 5

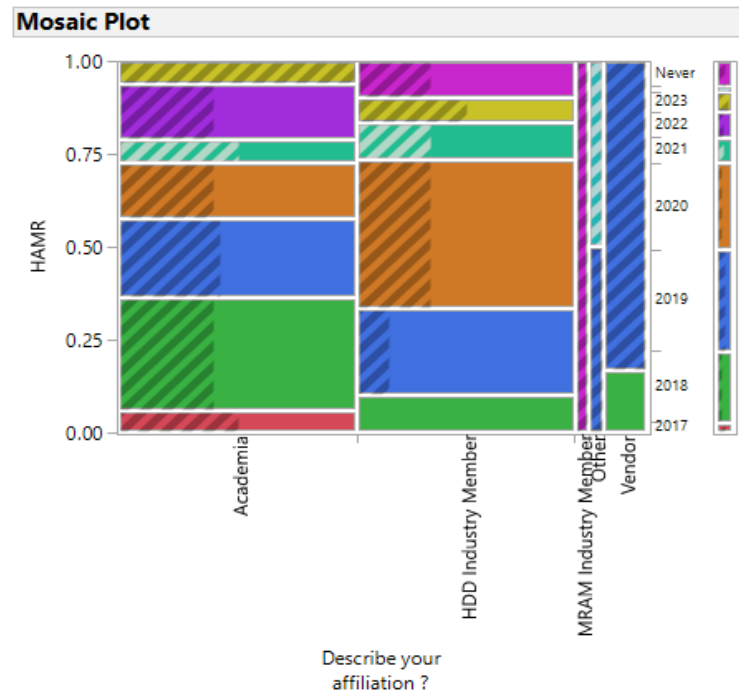


# By group

## BPM



## HAMR



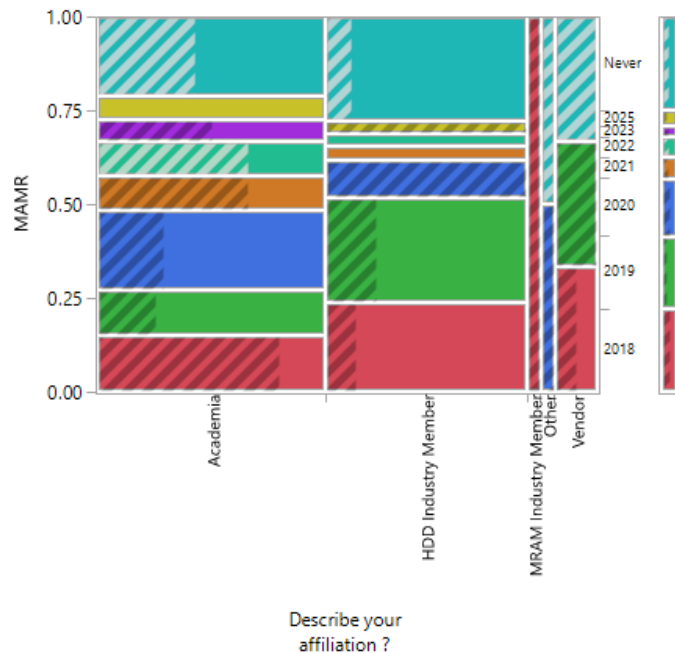
HDD industry pessimism for BPM is high

# By group

## MAMR

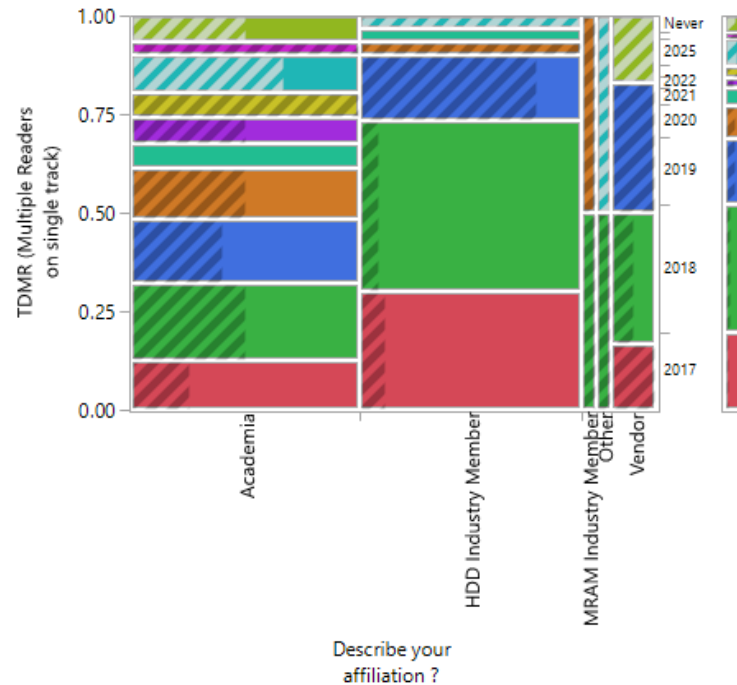
Contingency Analysis of MAMR By Describe your affiliation ?

Mosaic Plot



## TDMR

Mosaic Plot

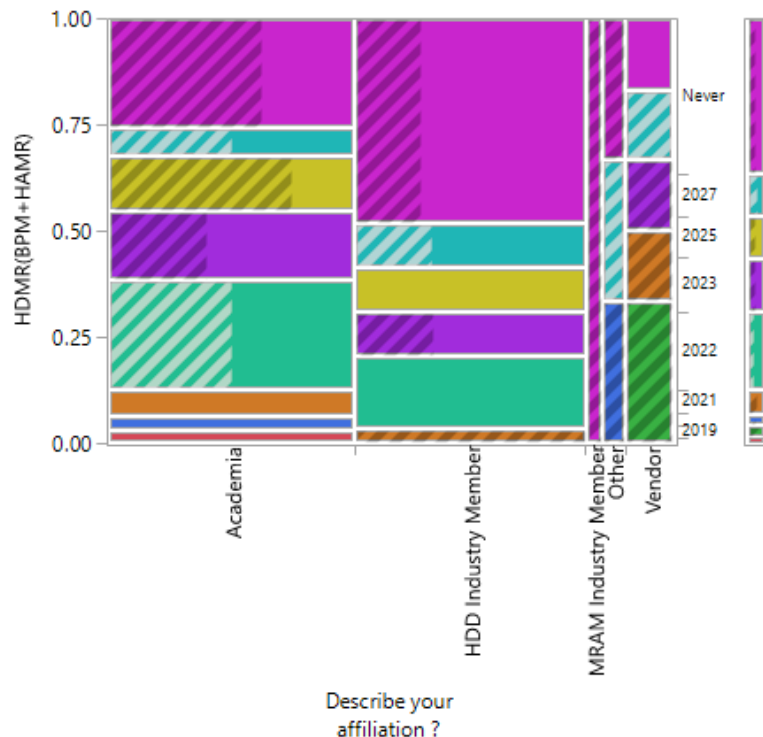


# By group

## Heated dot recording

### Contingency Analysis of HDMR(BPM + HAMR) By Describe your affiliation ?

Mosaic Plot



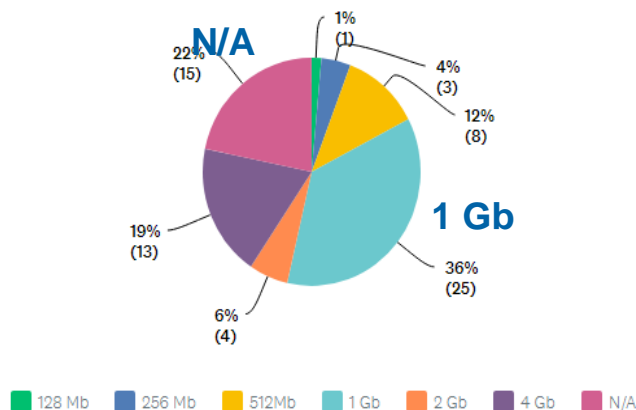
HDD industry pessimism again here.

# MRAM questions 1:2 (only 3 MRAM industry members)

## This Survey

What is the expected MRAM capacity (Megabits) per chip in 2020 ?

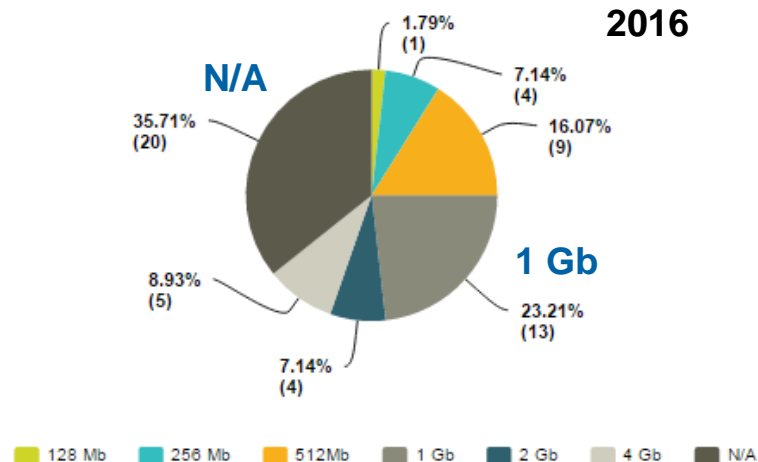
Answered: 69 Skipped: 10



	128 MB	256 MB	512MB	1 GB	2 GB	4 GB	N/A	TOTAL
(no label)	1% 1	4% 3	12% 8	36% 25	6% 4	19% 13	22% 15	69

What is the expected MRAM capacity (Megabits) per chip in 2020 ?

Answered: 56 Skipped: 4



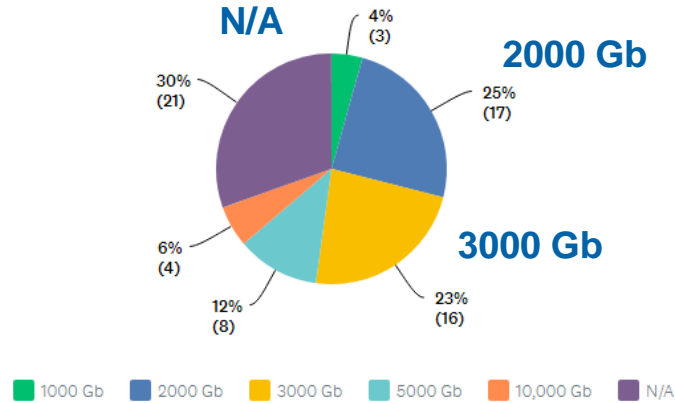
	128 Mb (1)	256 Mb (2)	512Mb (3)	1 Gb (4)	2 Gb (5)	4 Gb (6)	N/A	Total
(no label)	1.79% 1	7.14% 4	16.07% 9	35.71% 20	8.93% 5	7.14% 4	23.21% 13	56

# MRAM questions 2:2 (only 3 MRAM industry members)

## This Survey

What is the expected NAND capacity (Gigabits) per chip in 2020?

Answered: 69 Skipped: 10

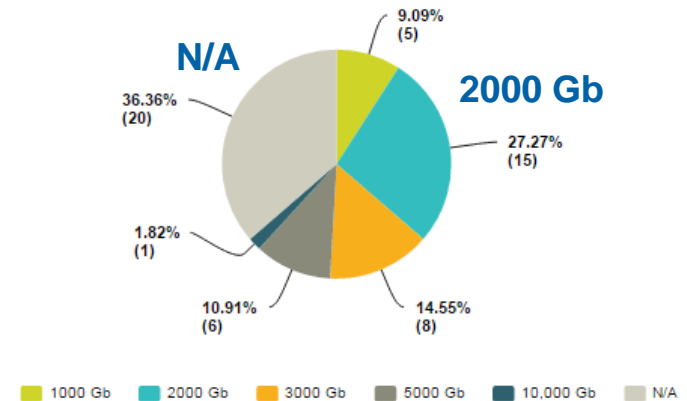


	1000 GB	2000 GB	3000 GB	5000 GB	10,000 GB	N/A	TOTAL
(no label)	4% 3	25% 17	23% 16	12% 8	6% 4	30% 21	69

2016

What is the expected NAND capacity (Gigabits) per chip in 2020?

Answered: 55 Skipped: 5



	1000 Gb	2000 Gb	3000 Gb	5000 Gb	10,000 Gb	N/A	Total	V A
(no label)	9.09% 5	27.27% 15	14.55% 8	10.91% 6	1.82% 1	36.36% 20	55	

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August 2 – 4, Tsukuba, Japan

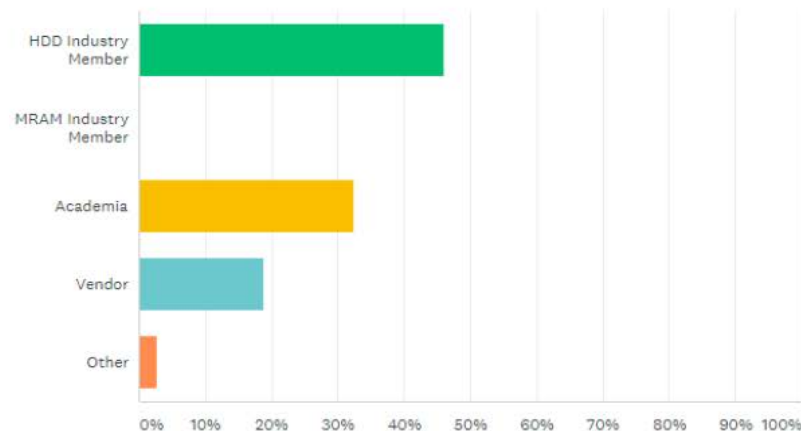
# Post conference update

## 37 – Post responses.

Not enough to separate by affiliation.

Will group together for now.

Answered: 37 Skipped: 0



ANSWER CHOICES	RESPONSES	
▼ HDD Industry Member	45.95%	17
▼ MRAM Industry Member	0.00%	0
▼ Academia	32.43%	12
▼ Vendor	18.92%	7
▼ Other	2.70%	1
TOTAL		37



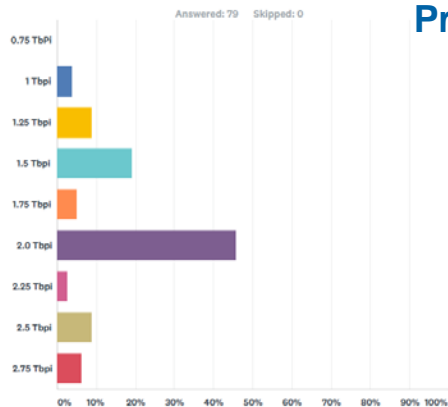
# Post Conference: Maximum ADC ~ 29 responses

- Median of 1.75 Tb/inch<sup>2</sup> +/-0.25
- A few optimistic voters for 2.5 Tb/inch<sup>2</sup>, and above.

Q2 What is the Maximum Areal Density Capability expected for Perpendicular/Shingled/Two dimensional - magnetic recording extensions?

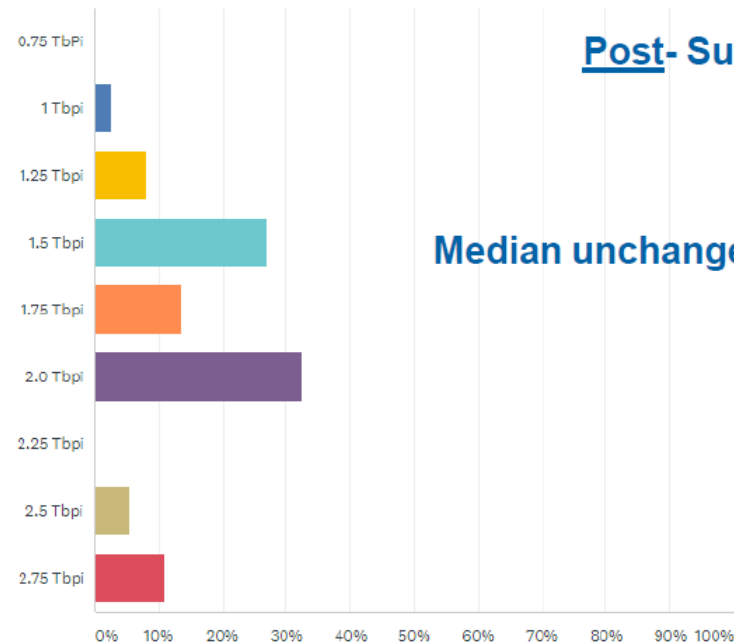
Answered: 37 Skipped: 0

Pre- Survey



Answer Choices	Responses
0.75 Tbpi	0.00% 0
1 Tbpi	3.80% 3
1.25 Tbpi	8.86% 7
1.5 Tbpi	18.99% 15
1.75 Tbpi	5.06% 4
2.0 Tbpi	45.57% 36
2.25 Tbpi	2.53% 2
2.5 Tbpi	8.86% 7
2.75 Tbpi	6.33% 5
Total	79

Post- Survey

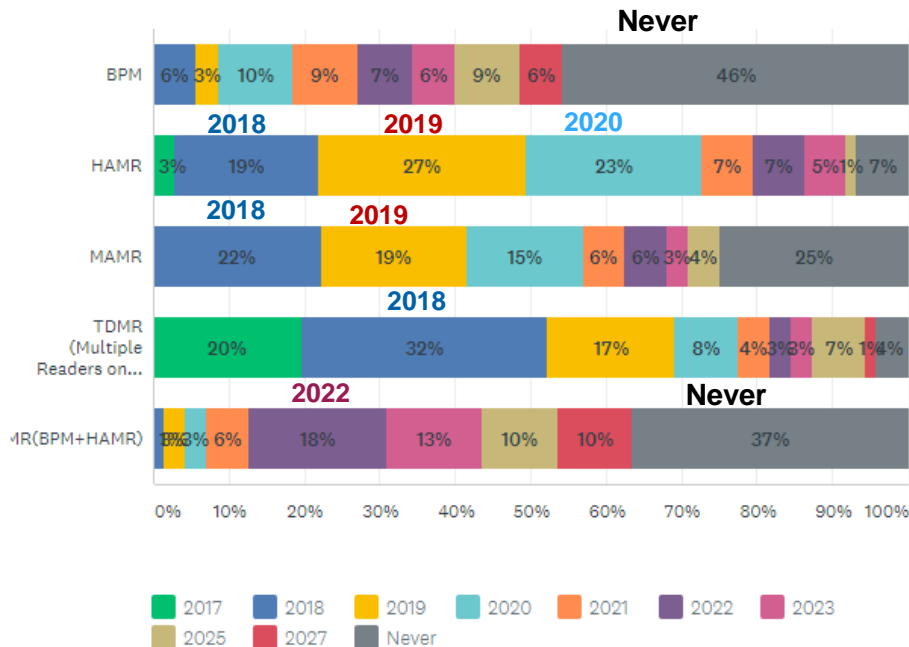


Median unchanged.

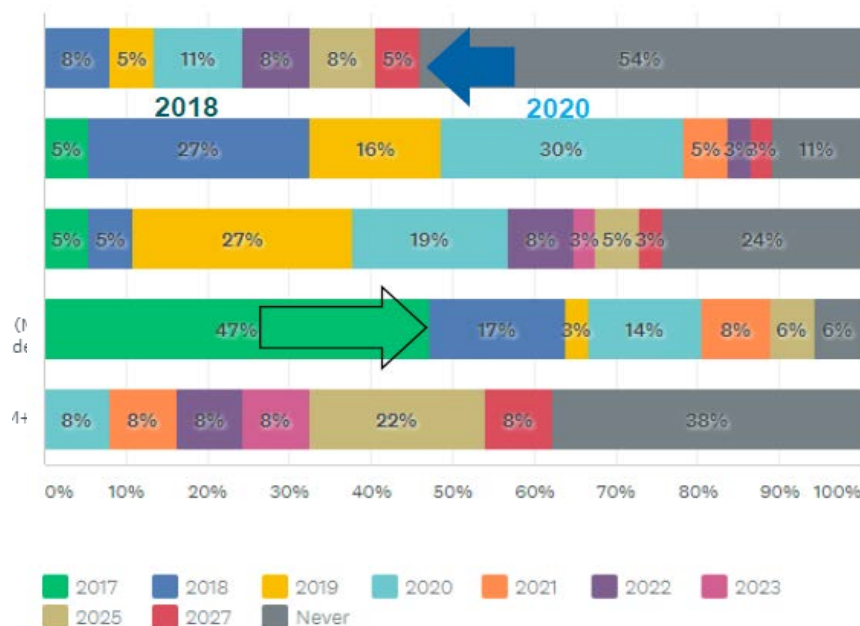
# Technology Survey

What is the expected Year of Technology introduction to HDD Products ?

## Pre-Survey



## Post-Survey



Pessimism rates similar, TDMR in 2017 is key, MAMR settles into 2019

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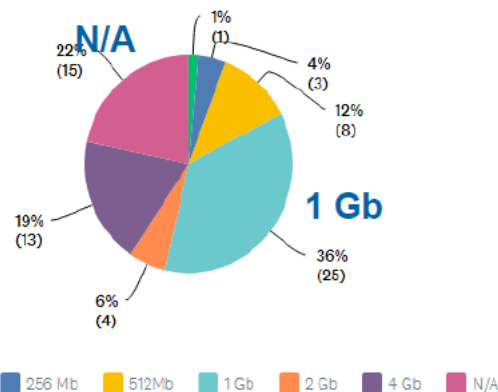
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# MRAM questions 1:2

## Pre Survey

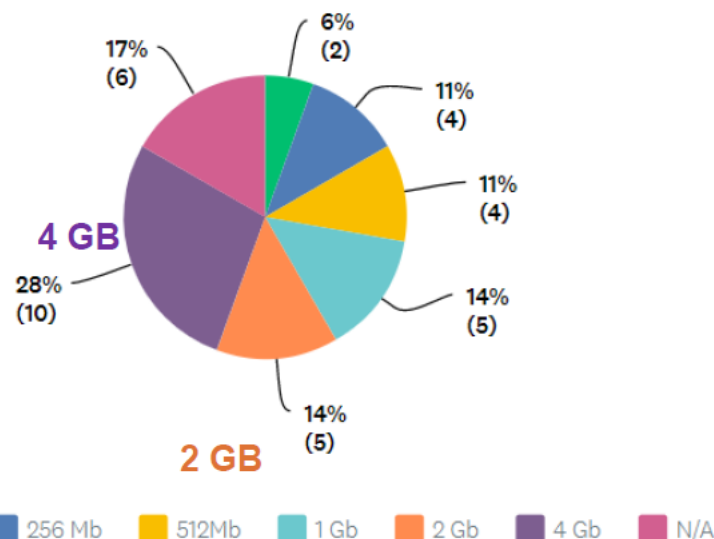
What is the expected MRAM capacity (Megabits) per chip in 2020 ?

Answered: 69 Skipped: 10



	128 MB	256 MB	512MB	1 GB	2 GB	4 GB	N/A	TOTAL
(no label)	1%	4%	12%	36%	6%	19%	22%	69
	1	3	8	25	4	13	15	

## Post Survey



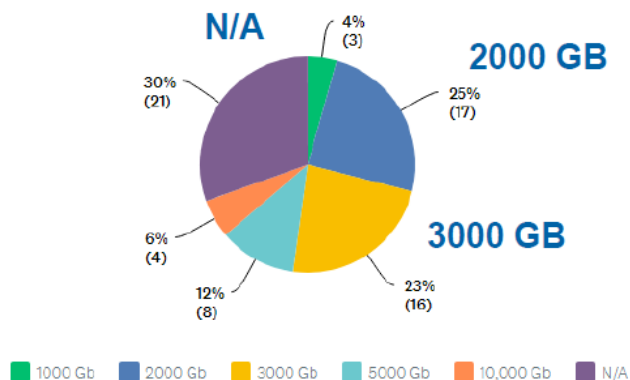
4 GB over 1 GB is favored.

# MRAM questions 2:2

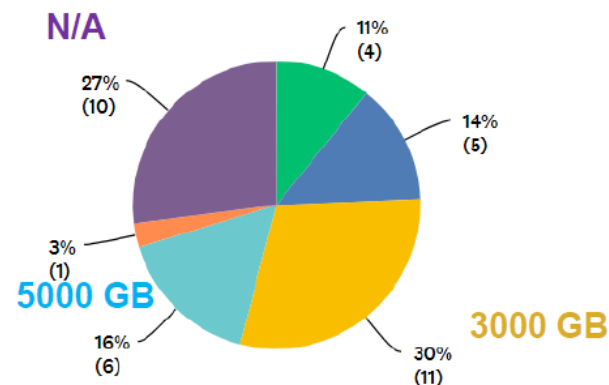
## pre Survey

What is the expected NAND capacity (Gigabits) per chip in 2020?

Answered: 69 Skipped: 10



## Post Survey



	1000 GB	2000 GB	3000 GB	5000 GB	10,000 GB	N/A	TOTAL
(no label)	4% 3	25% 17	23% 16	12% 8	6% 4	30% 21	69

More optimism to 5 TB nodes.

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# Compare with earlier surveys

# Technology pessimism: Compare 2017 with 2016-2013

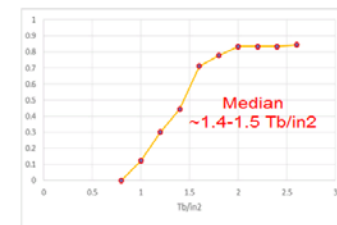
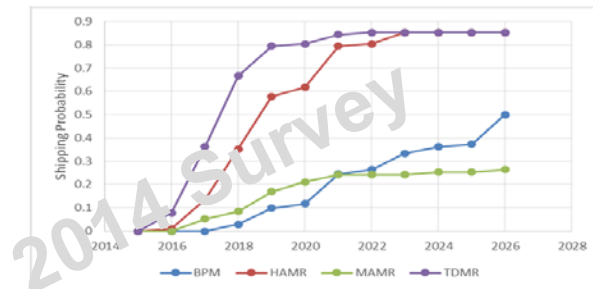
More respondents/responses.

Warning: Have not isolated repeat votes

Technology	BPM	HAMR	MAMR	TDMR	HD MR
Will never ship (2017)	46%	7%	<b>25%</b>	4%	<b>37%</b>
Will never ship (2016)	41%	<b>10%</b>	39%	3%	21%
Will never ship (2015)	37%	<b>3%</b>	42%	<b>2%</b>	16%
Will never ship (2014)	47%	14%	73%	15%	N/A
Will never ship (2013)	40%	29%	28%	23%	N/A

	BPM	HAMR	MAMR	TDMR
will never ship	47%	14%	73%	15%
(2013 value)	40%	29%	28%	23%
Mean intro year	2021.8	2018.4	2018.8	2016.8
(2013 value)	2019.9	2017.9	2017.1	2017.1

102 data points • Only 12 from Academia



Ultimate Limit of PMR/SMR/TDMR

From left to right..

- **BPM** appears stable.
- **HAMR** confidence bounced back
- **MAMR** hit a bad patch 2014, stabilized
- **TDMR** confidence very high, and stable
- **HD MR** confidence – higher than BPM- but dropping.

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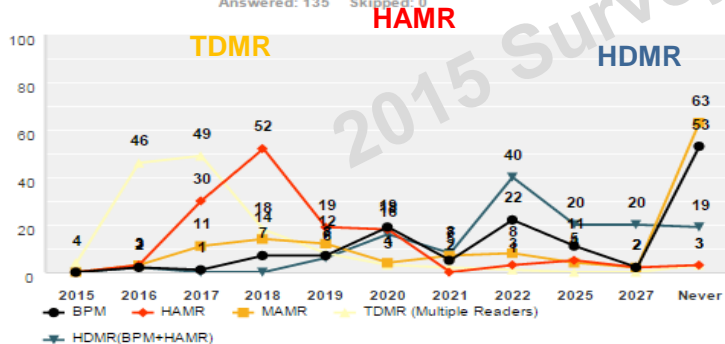
# Technology Introduction year

Technology	BPM	HAMR	MAMR	TDMR	HDMR (new)
Median year (2017)	2024*	2019	2021*	2018	2023*
Median year (2016)	2024*	2018	2020*	2017	2023
Median year (2015)	2023*	2018	2020*	2017	2022
Median year (2014)	2022	2018	2018	2017	N/A
Median year (2013)	2022	2018	2018	2017	N/A

\* Median questionable due to “never” response rate

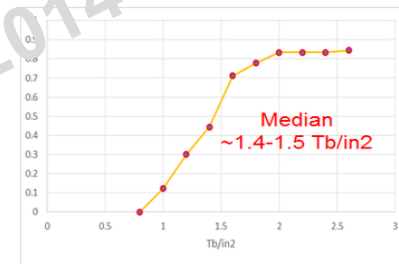
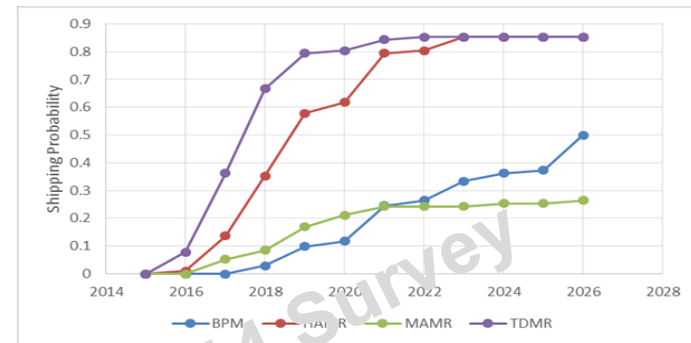
What is the expected Year of Technology introduction to HDD Products ?

Answered: 135 Skipped: 0



	BPM	HAMR	MAMR	TDMR
will never ship	47%	14%	73%	15%
(2013 value)	40%	29%	28%	23%
Mean intro year	2021.8	2018.4	2018.8	2016.8
(2013 value)	2019.9	2017.9	2017.1	2017.1

102 data points ♦ Only 12 from Academia



The 28th Magnetic Recording Conference (TMRC2017)

August 2 – 4, Tsukuba, Japan

# TMRC 2018

The 29<sup>th</sup> Magnetic Recording Conference

Date: **Week of August 6, 2018**

Venue: **Western Digital, Milpitas Campus,  
Milpitas, California, USA.**

## Topics of interest include:

- *Advanced Magnetic Recording for > 2 Tbits/in<sup>2</sup> including Readers, Writers, Servo, Tribology, HDI, Signal Processing.*
- *Two-Dimensional Magnetic Recording (TDMR)*
- *Heat Assisted Magnetic Recording (HAMR)*
- *Heated Dot Magnetic Recording (HDMR)*
- *Magnetic Solid State Memory (MRAM, STT-RAM, Racetrack)*
- *Alternative Magnetic Recording Technologies (SMR, MAMR, Tape, All Optical Switching)*
- *Magnetic Solid State Memory (MRAM, STT-MRAM, VC-MRAM, SOT-MRAM)*
- *Fundamentals (Metrology, Tooling, Materials, Recording Physics)*

Hosted By: ***Western Digital and UCSD (CMRR)***





advanced film project advanced technology incubation aimr **aist** argonne national laboratory bhd carnegie mellon university  
chulalongkorn university cnrs d institute japan daido steel co data security inc division of applied physics dod fuji electric sdn fujifilm  
fujitsu limited furuya metal co gifu university gmw associates headway technologies hgst a western digital company  
ibm research zurich imram inc indian institute of science institute of physics of czech academy of sciences jx nippon mining  
kanazawa university kansai university kogakuin univ kojundo chemical laboratory co kyoto university ltd marvell semiconductor  
metals corporation mie university mitsui mining nagoya university nanyang technological university national central university  
national chung hsing university  
**national institute for materials science**  
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spintronics research center tanaka kikinzo kogyo tdk corporation technology  
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tokyo institute of technology toshiba corp univ university of tsukuba vienna university of technology  
waseda university western digital corporation