

TMRC 2018 industry survey.
08/12/18

Chris Rea



Survey this year 1/2

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

* 1. Describe your affiliation ?

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

Survey issued in 2 waves:

- **First survey:** up to day before conference start.
- **This preview summary**
- **Second survey:** issued Thursday morning of conference.
- **Goal:** look at change in perspectives due to meeting.

* 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 ?

	2018	2019	2020	2021	2022	2023	2025	2027	2029	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"/>
HDMR(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 this year 2/2

MRAM questions....

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

256 Mb

512Mb

1 Gb

2 Gb

4 Gb

N/A

☐☐☐☐☐☐

5. What is the expected EMBEDDED MRAM capacity (Megabits) per chip in 2020

256 Mb

512Mb

1 Gb

2 Gb

4 Gb

N/A

☐☐☐☐☐☐

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

1000 Gb

2000 Gb

3000 Gb

5000 Gb

10,000 Gb

N/A

☐☐☐☐☐☐

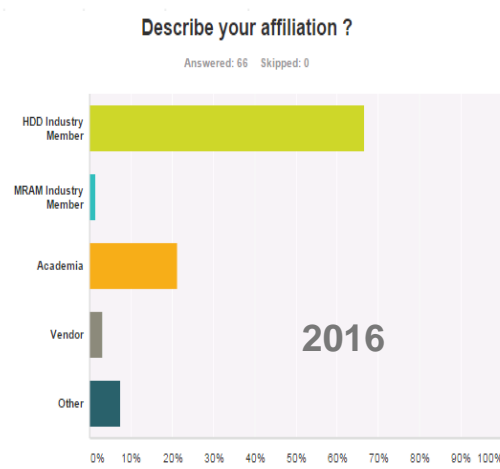
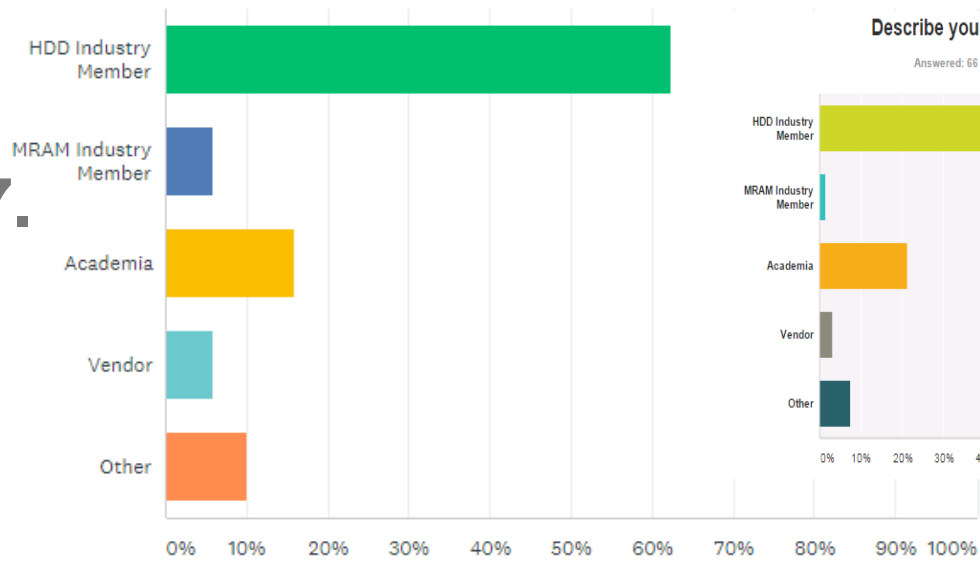
TMRC 2018 _

Part 1: pre conference Survey

Population of respondents up to 08/08/2018 (pre conference)

Describe your affiliation ?

Answered: 69 Skipped: 0



As with 2015/16/17.
Dominant
responses from
HDD members.

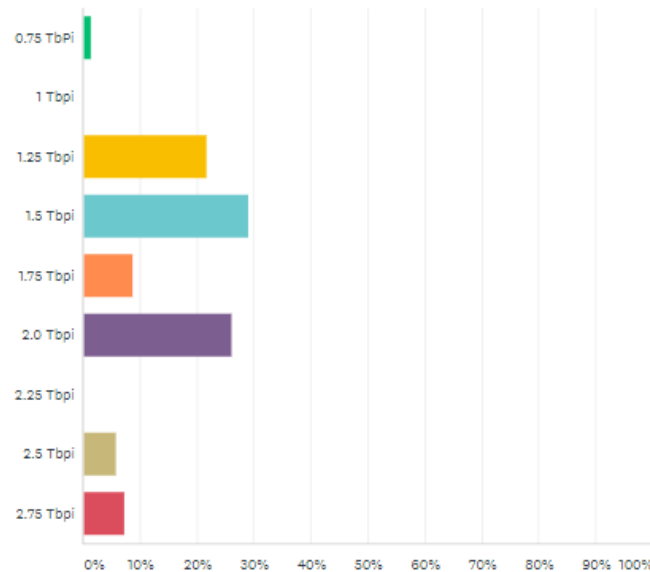
ANSWER CHOICES	RESPONSES	
▼ HDD Industry Member	62.32%	43
▼ MRAM Industry Member	5.80%	4
▼ Academia	15.94%	11
▼ Vendor	5.80%	4
▼ Other	10.14%	7
TOTAL	69	

Maximum ADC

- Median of 1.5Tb/inch² +/-0.25, mean of 1.75 Tb/inch²
- A few optimistic voters for 2.5 Tb/inch², and above.
- Bimodality between Academia and Industry (lower mode for industry)
- Pattern very similar to 2016

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

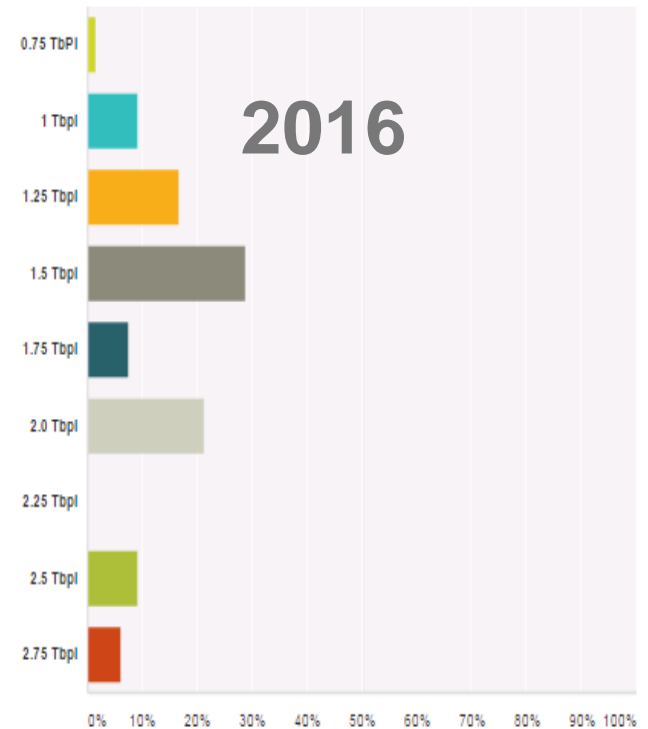
Answered: 69 Skipped: 0



ANSWER CHOICES	RESPONSES
▼ 0.75 TbPi	1.45% 1
▼ 1 Tbpi	0.00% 0
▼ 1.25 Tbpi	21.74% 15
▼ 1.5 Tbpi	28.99% 20
▼ 1.75 Tbpi	8.70% 6
▼ 2.0 Tbpi	26.09% 18
▼ 2.25 Tbpi	0.00% 0
▼ 2.5 Tbpi	5.80% 4
▼ 2.75 Tbpi	7.25% 5
TOTAL	69

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

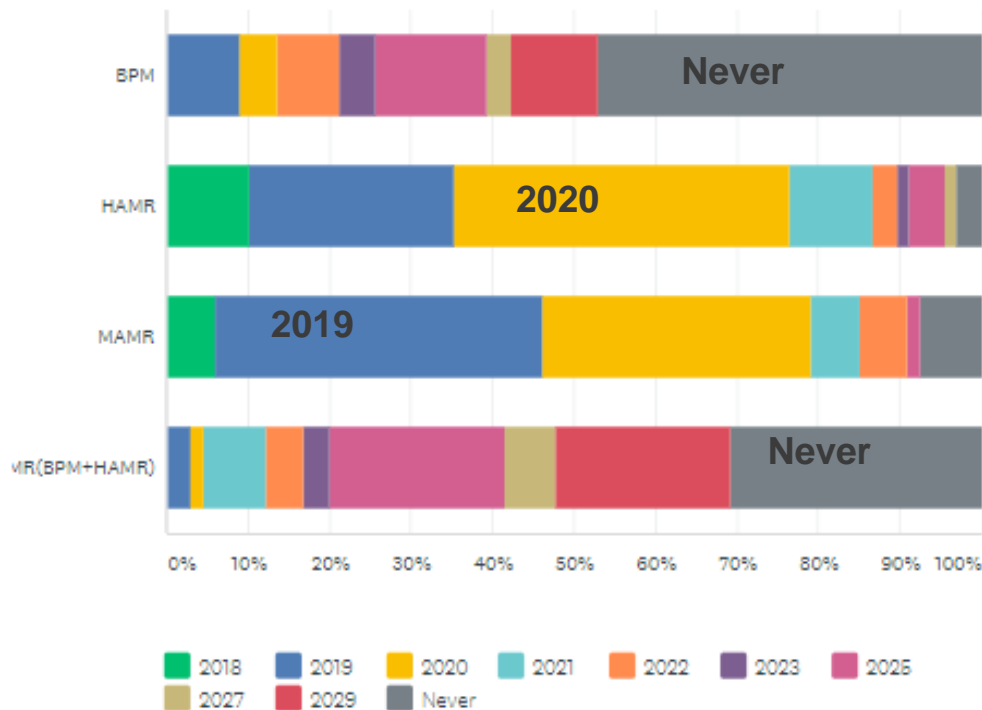
Answered: 66 Skipped: 0



Technology Survey- before conference

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

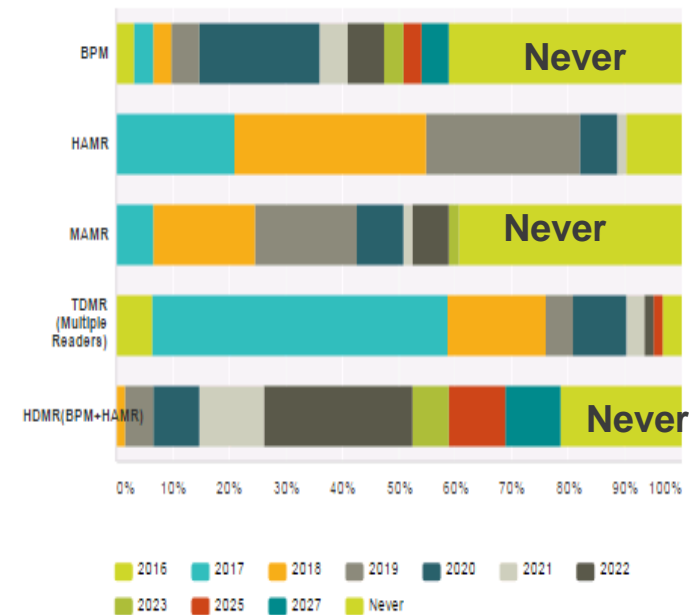
Answered: 68 Skipped: 1



2016

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

Answered: 64 Skipped: 2



Pessimism for MAMR reduced

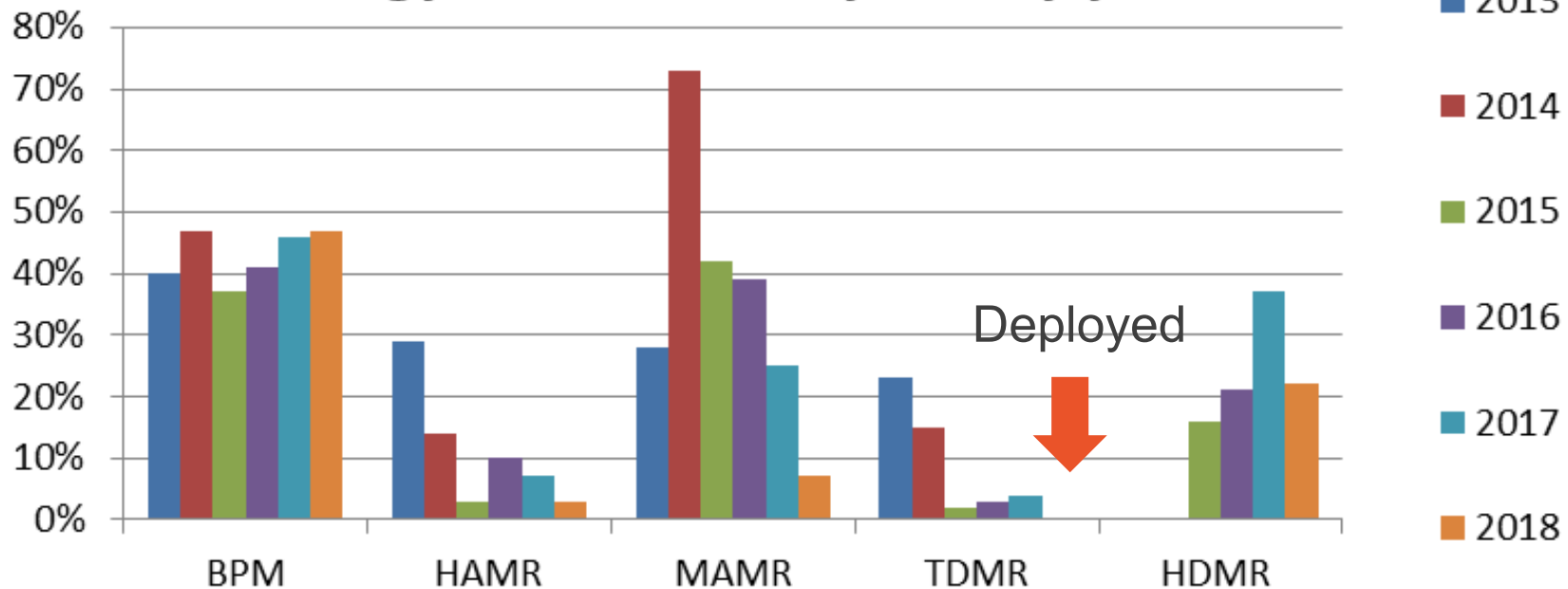
But reduction first appeared 2017 TMRC.

BPM/Heated Dot remains pessimistic

Focus in next slide on specific fraction of people that think a technology will not work

Technology pessimism: Compare 2018 with 2017-2013

Technology Pessimism - by survey year



From left to right..

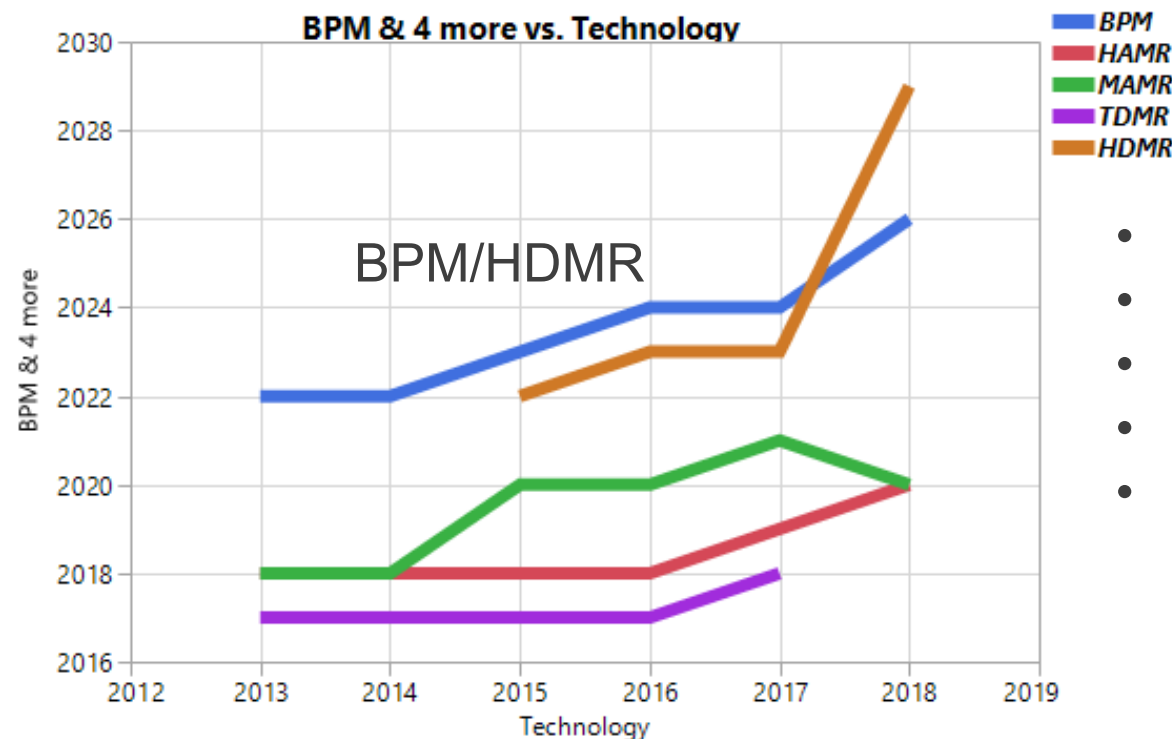
- BPM appears stable and poor.
- HAMR confidence steady improved.
- MAMR hit a bad patch 2014, started recovery in 2016-2017, and significantly improved this year.
- TDMR Launched 2017 into product – so removed 2018.
- HDMR confidence – higher than BPM but still poor and variable.

Technology	BPM	HAMR	MAMR	TDMR	HDMR
2013	40%	29%	28%	23%	
2014	47%	14%	73%	15%	
2015	37%	3%	42%	2%	16%
2016	41%	10%	39%	3%	21%
2017	46%	7%	25%	4%	37%
2018	47%	3%	7%		22%

Technology Introduction year

Technology	BPM	HAMR	MAMR	TDMR	HDMR
2013	2022	2018	2018	2017	N/A
2014	2022	2018	2018	2017	N/A
2015	2023*	2018	2020*	2017	2022
2016	2024*	2018	2020*	2017	2023
2017	2024*	2019	2021*	2018	2023*
2018	2026*	2020	2020	-	2029*

*Pessimism is high
So confidence on
introduction year is
poor.

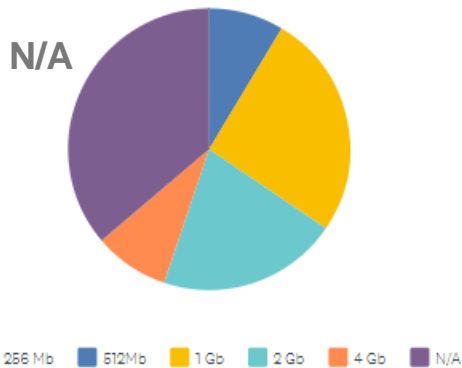


- BPM continues to drift.
- HDMR has taken a push out.
- MAMR pulls back.
- HAMR starting to push.
- TDMR Launched 2017

MRAM questions

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

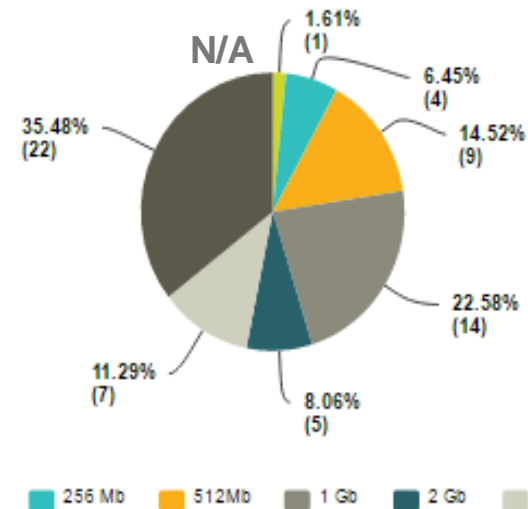
Answered: 58 Skipped: 11



	256 MB	512MB	1 GB	2 GB	4 GB	N/A	TOTAL
(no label)	0.00% 0	8.62% 5	25.86% 15	20.69% 12	8.62% 5	36.21% 21	58

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

Answered: 62 Skipped: 4

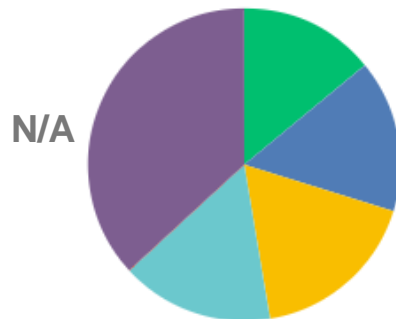


	128 Mb (1)	256 Mb (2)	512Mb (3)	1 Gb (4)	2 Gb (5)	4 Gb (6)	N/A	Total
(no label)	1.61% 1	6.45% 4	14.52% 9	22.58% 14	8.06% 5	11.29% 7	35.48% 22	62

2016

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

Answered: 57 Skipped: 12

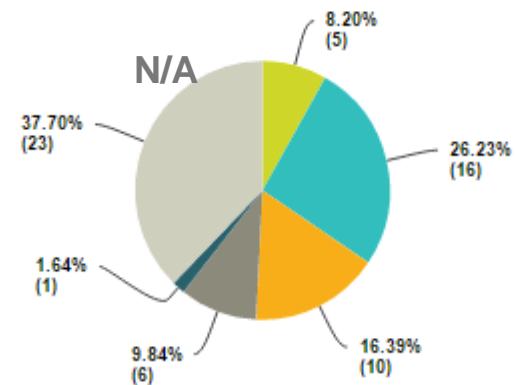


1000 Gb 2000 Gb 3000 Gb 5000 Gb 10,000 Gb N/A

2016

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

Answered: 61 Skipped: 5



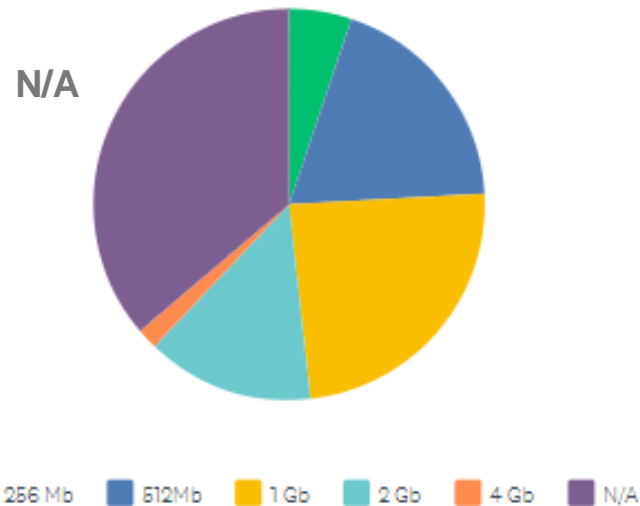
1000 Gb 2000 Gb 3000 Gb 5000 Gb 10,000 Gb N/A

	1000 Gb	2000 Gb	3000 Gb	5000 Gb	10,000 Gb	N/A	Total	Weighted Average
(no label)	8.20% 5	26.23% 16	16.39% 10	9.84% 6	1.64% 1	37.70% 23	61	2.53

New MRAM Question this year

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

Answered: 58 Skipped: 11



	256 MB	512MB	1 GB	2 GB	4 GB	N/A	TOTAL	WEIGHTED AVERAGE
(no label)	5.17% 3	18.97% 11	24.14% 14	13.79% 8	1.72% 1	36.21% 21	68	3.97

TRMC 2018

Part 2: post conference Survey

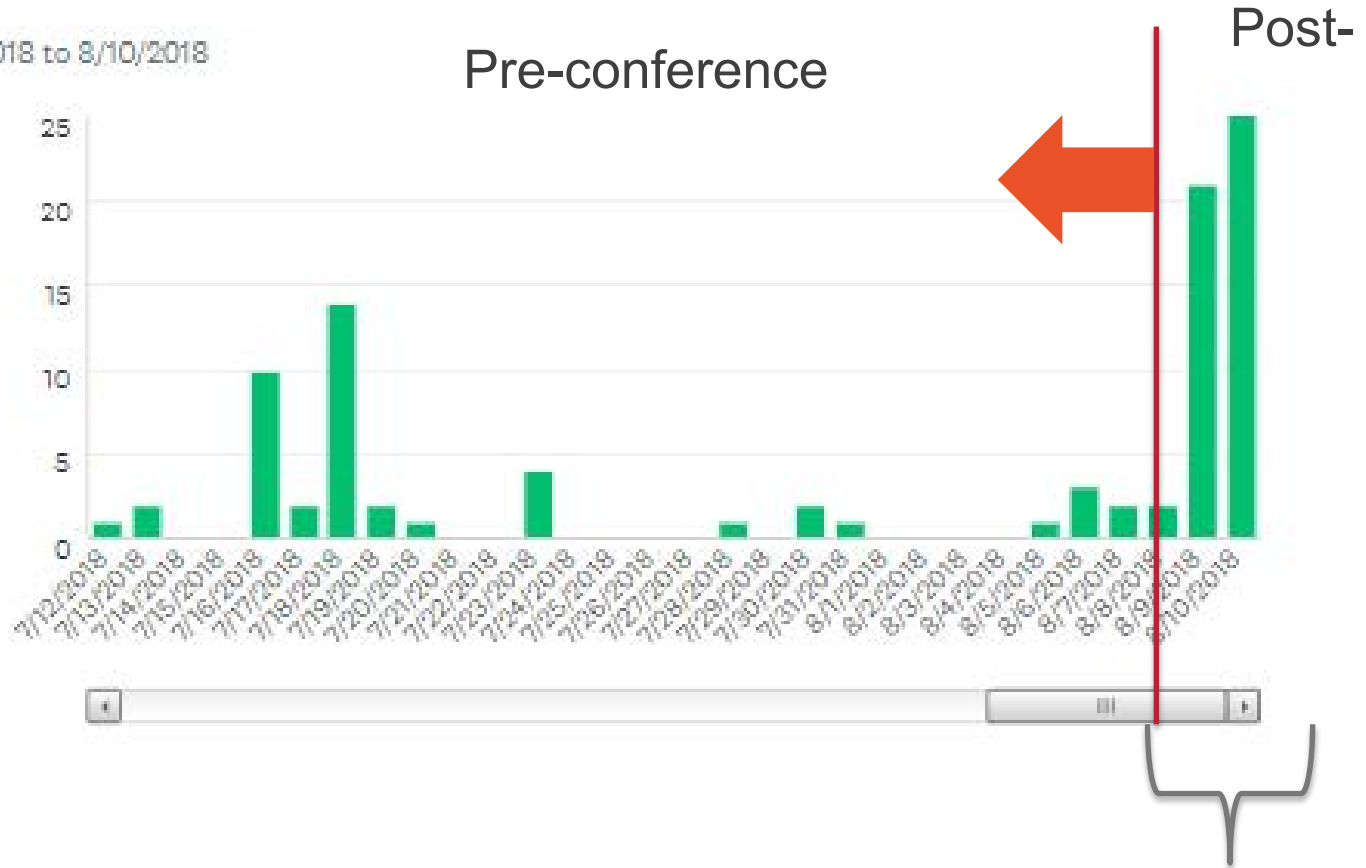
Or: “Did we change your mind?”



Reponses vs. time: Defined 8/8/2018 as pre/post boundary.

First: 3/30/2018

Zoom: 7/12/2018 to 8/10/2018



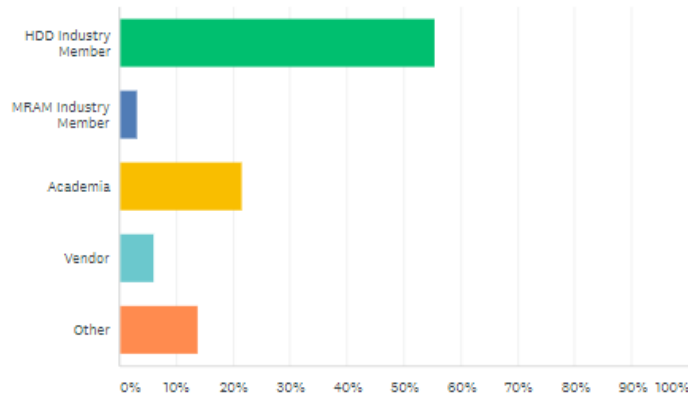
Note: Conference ran 8/8-8/10

Distribution of voters

Post-conference

Describe your affiliation ?

Answered: 65 Skipped: 0

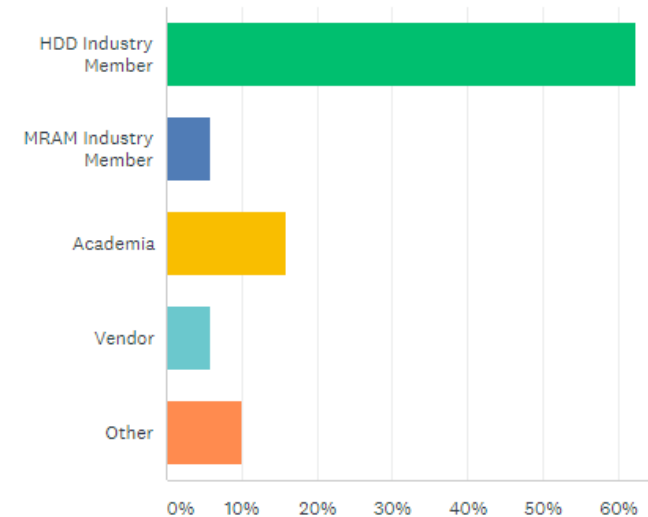


ANSWER CHOICES	RESPONSES
HDD Industry Member	55.38% 36
MRAM Industry Member	3.08% 2
Academia	21.54% 14
Vendor	6.15% 4
Other	13.85% 9
TOTAL	65

PRE -conference

Describe your affiliation ?

Answered: 69 Skipped: 0



Similar HDD Industry heavy weighting of response.

But we do have enough responses from Academia that we can contrast with HDD
Which leads to some interesting (unexpected) observations...

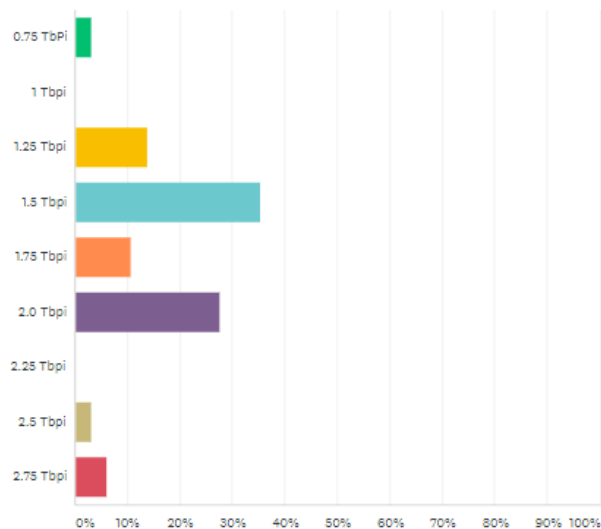
Maximum ADC- Pre/Post

- Median of 1.5Tb/inch² +/-0.25, mean of 1.75 Tb/inch²
- A few optimistic voters for 2.5 Tb/inch², and above.
- Bimodality between Academia and Industry (lower mode for industry)- stays...

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

Post-conference

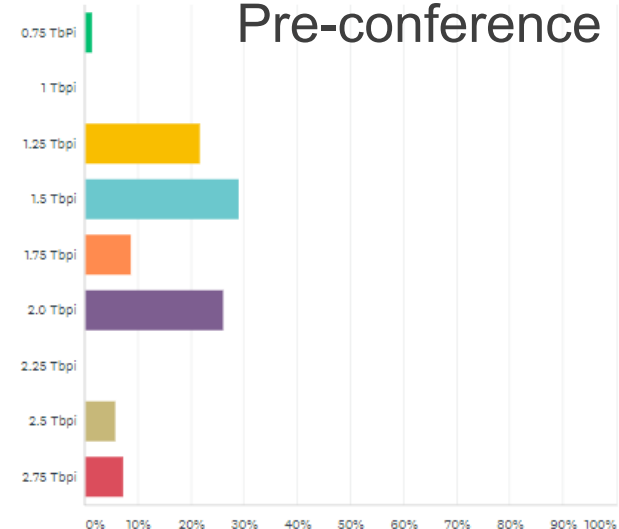
Answered: 65 Skipped: 0



ANSWER CHOICES	RESPONSES
▼ 0.75 TbPi (1)	3.08% 2
▼ 1 Tbpi (2)	0.00% 0
▼ 1.25 Tbpi (3)	13.85% 9
▼ 1.5 Tbpi (4)	35.38% 23
▼ 1.75 Tbpi (5)	10.77% 7
▼ 2.0 Tbpi (6)	27.69% 18
▼ 2.25 Tbpi (7)	0.00% 0
▼ 2.5 Tbpi (8)	3.08% 2
▼ 2.75 Tbpi (9)	6.15% 4
TOTAL	65

Pre-conference

swered: 69 Skipped: 0

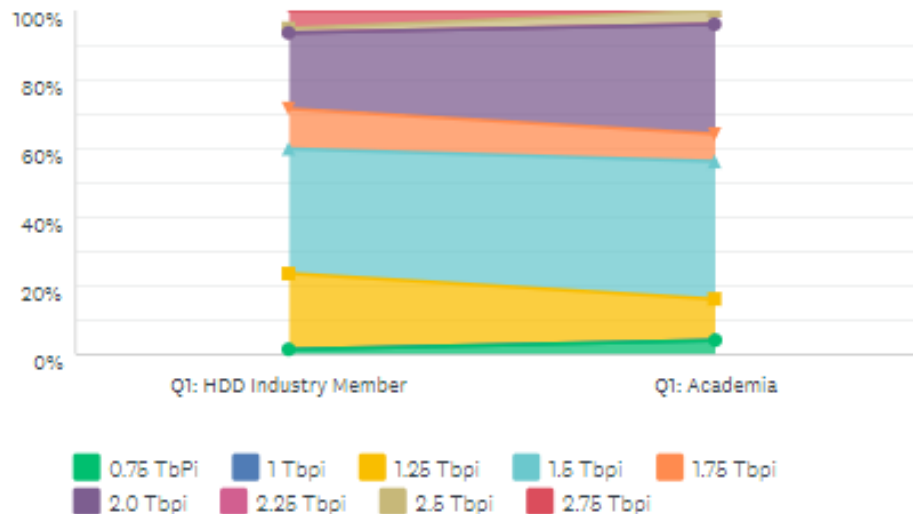


ANSWER CHOICES	RESPONSES
▼ 0.75 TbPi	1.45% 1
▼ 1 Tbpi	0.00% 0
▼ 1.25 Tbpi	21.74% 18
▼ 1.5 Tbpi	28.99% 20
▼ 1.75 Tbpi	8.70% 6
▼ 2.0 Tbpi	26.09% 18
▼ 2.25 Tbpi	0.00% 0
▼ 2.5 Tbpi	5.80% 4
▼ 2.75 Tbpi	7.25% 5
TOTAL	69

Projected ADC – by Group

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

Answered: 102 Skipped: 0



Academia tends to lean to 2 TBPSI.

Industry 1.5, or lower.

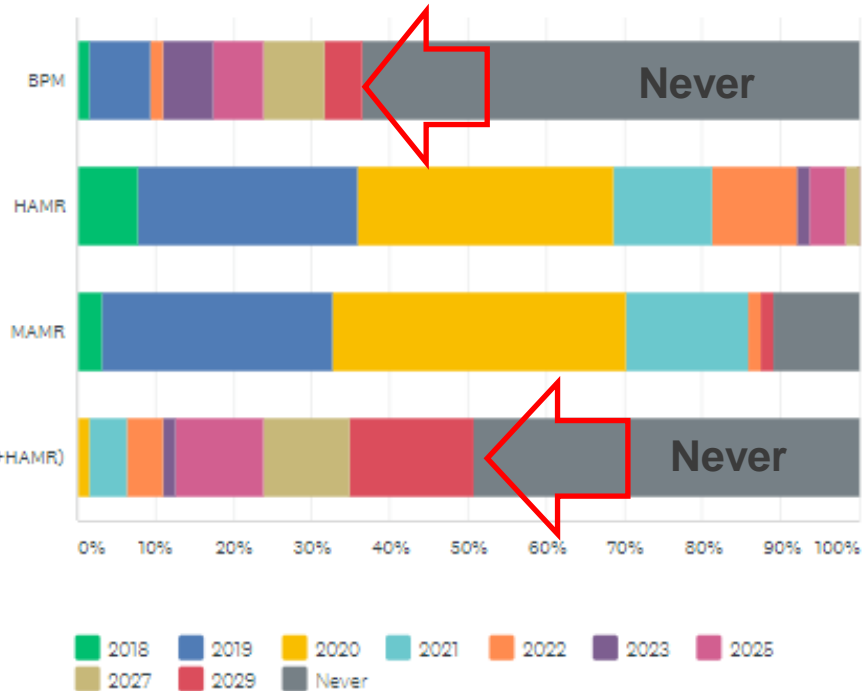
	0.75 TBPI (1)	1 TBPI (2)	1.25 TBPI (3)	1.5 TBPI (4)	1.75 TBPI (5)	2.0 TBPI (6)	2.25 TBPI (7)	2.5 TBPI (8)	2.75 TBPI (9)	TOTAL
Q1: HDD Industry Member	1.30% 1	0.00% 0	22.08% 17	36.36% 28	11.69% 9	22.08% 17	0.00% 0	1.30% 1	5.19% 4	75.49% 77
Q1: Academia	4.00% 1	0.00% 0	12.00% 3	40.00% 10	8.00% 2	32.00% 8	0.00% 0	4.00% 1	0.00% 0	24.51% 25
Total Respondents	2	0	20	38	11	25	0	2	4	102

Technology Survey- pre vs. post

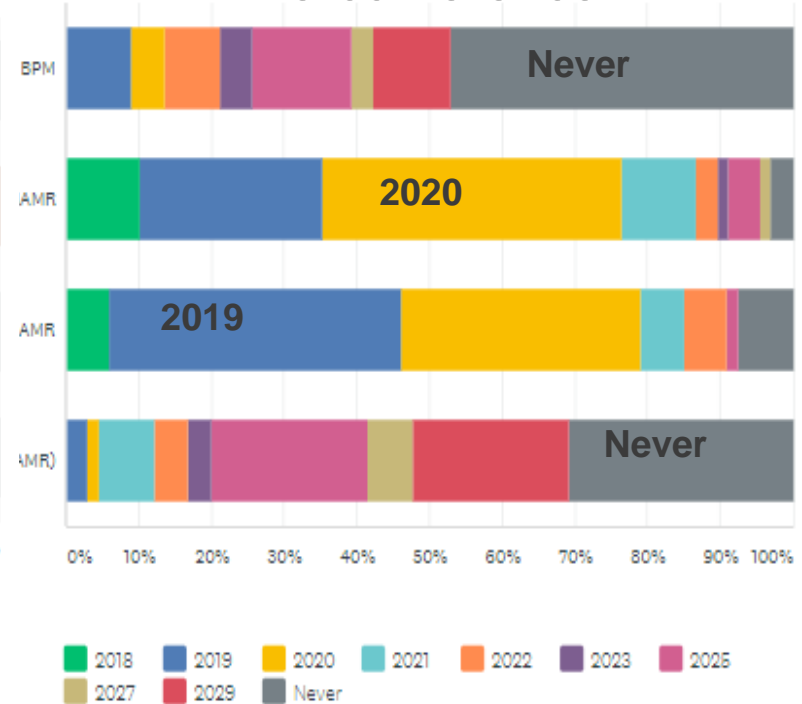
What is the expected Year of Technology introduction to HDD Products ?

skipped: 1

Post-conference

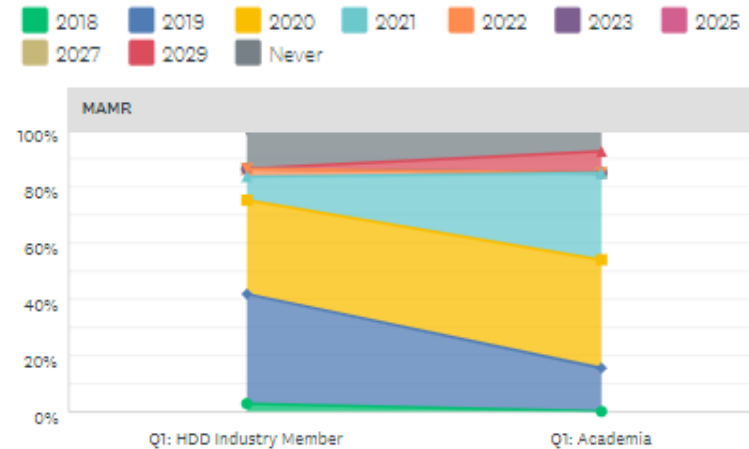
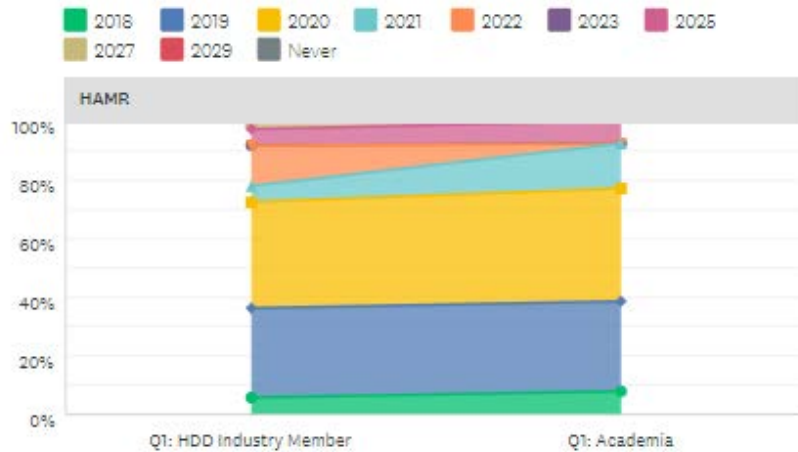
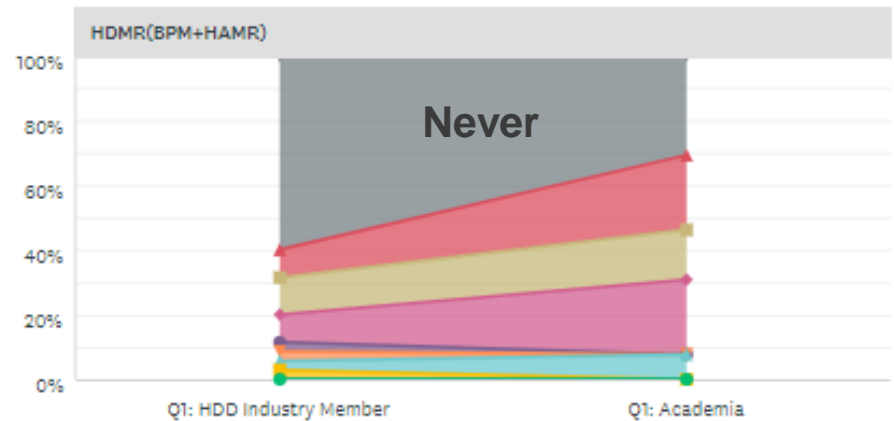
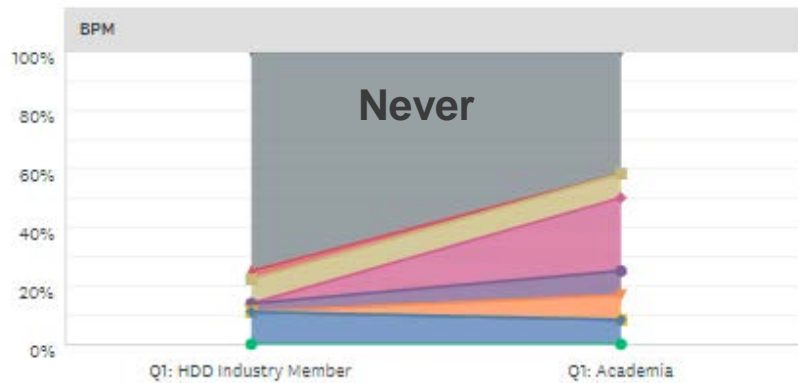


Pre-conference



Pessimism post conference for BPM and Sister HDMR (BPM+HAMR) continues to grow, otherwise small changes on MAMR/HAMR.

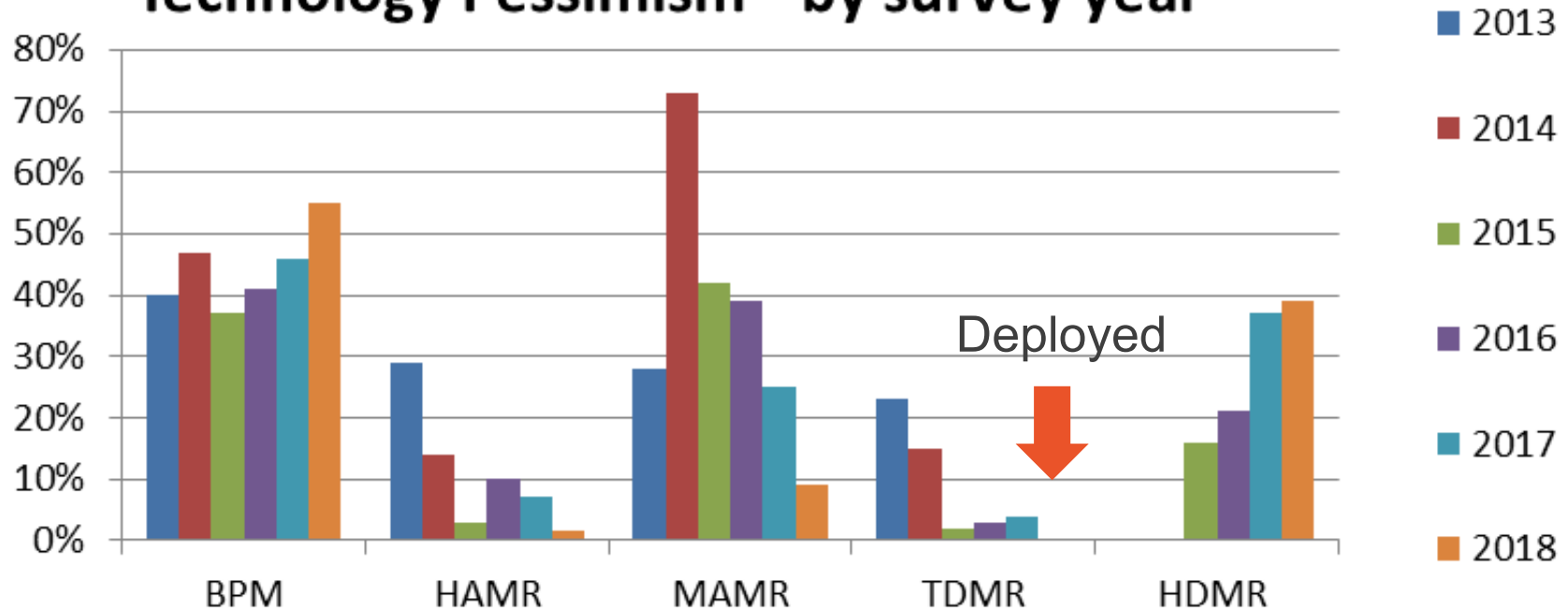
Breakdown between Academia and Industry



- BPM/HDMR: HDD industry vote is extremely negative.
- HAMR Industry/Academia closely aligned
- MAMR: Disconnect between academia and industry, compared to industry – academia is more pessimistic in timing.

Revised: Technology pessimism: Compare 2018 (pre+post) with 2017-2013

Technology Pessimism - by survey year



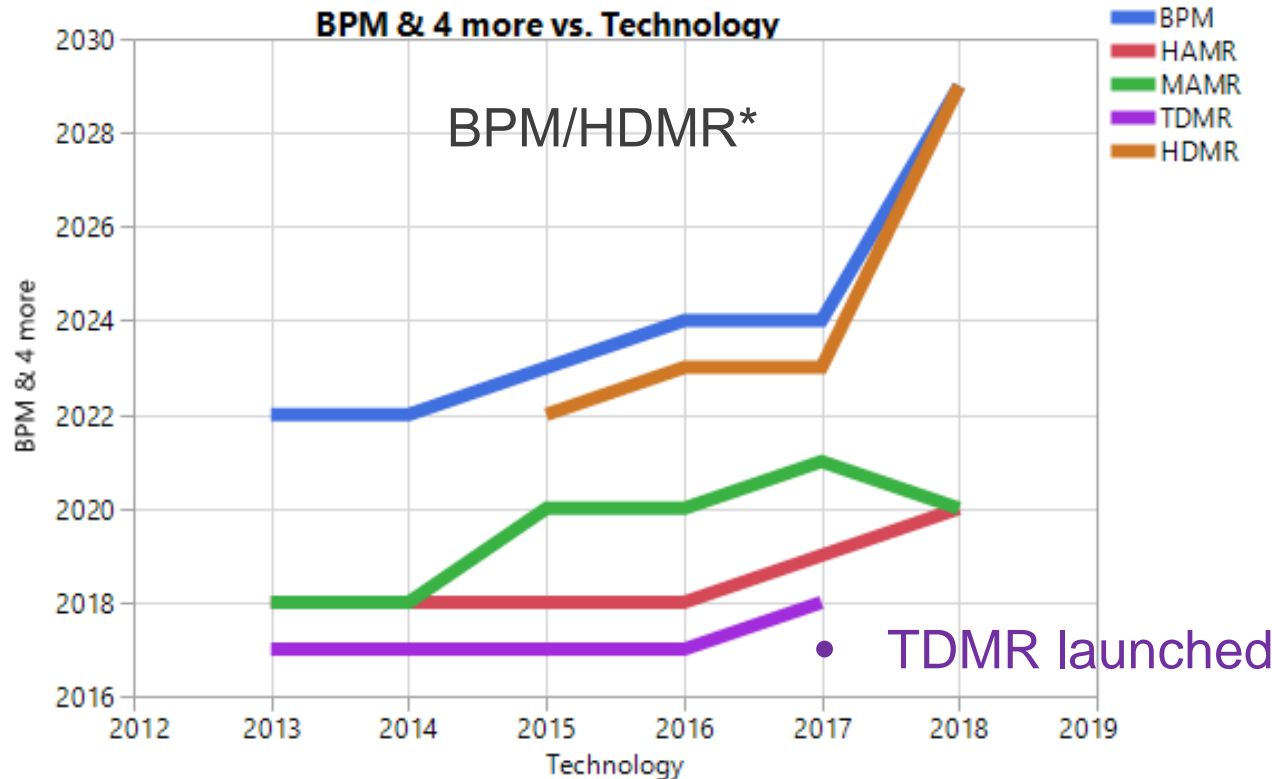
From left to right..

- BPM now degrading
- HAMR confidence steady improved.
- MAMR hit a bad patch 2014, started recovery in 2016-2017, and significantly improved this year.
- TDMR Launched 2017 into product – so removed 2018.
- HDMR confidence – higher than BPM but degraded last 2 years.

Technology	BPM	HAMR	MAMR	TDMR	HDMR
2013	40%	29%	28%	23%	
2014	47%	14%	73%	15%	
2015	37%	3%	42%	2%	16%
2016	41%	10%	39%	3%	21%
2017	46%	7%	25%	4%	37%
2018	55%	2%	9%		39%

Technology Introduction year (pre and Post)

Graph Builder



*Pessimism is high
So confidence on
introduction year is
poor.

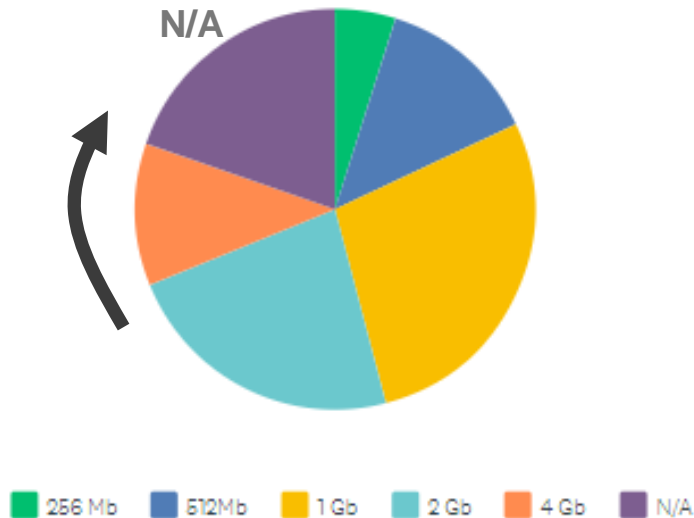
- BPM continues to drift.
- HDMR has taken a push out.
- MAMR pulls back.
- HAMR starting to push.
- TDMR Launched 2017

MRAM questions: Stand Alone capacity

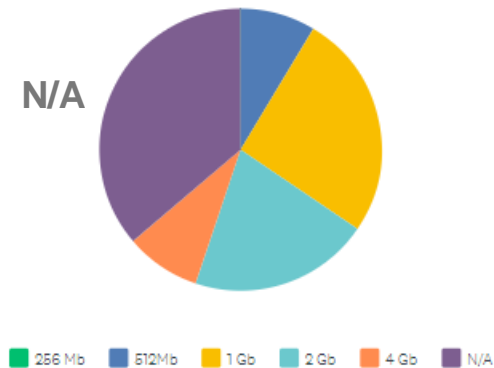
What is the expected STAND_ALONE MRAM capacity (Megabits) per chip in 2020?

Answered: 58 Skipped: 11

Post-conference



Pre-conference



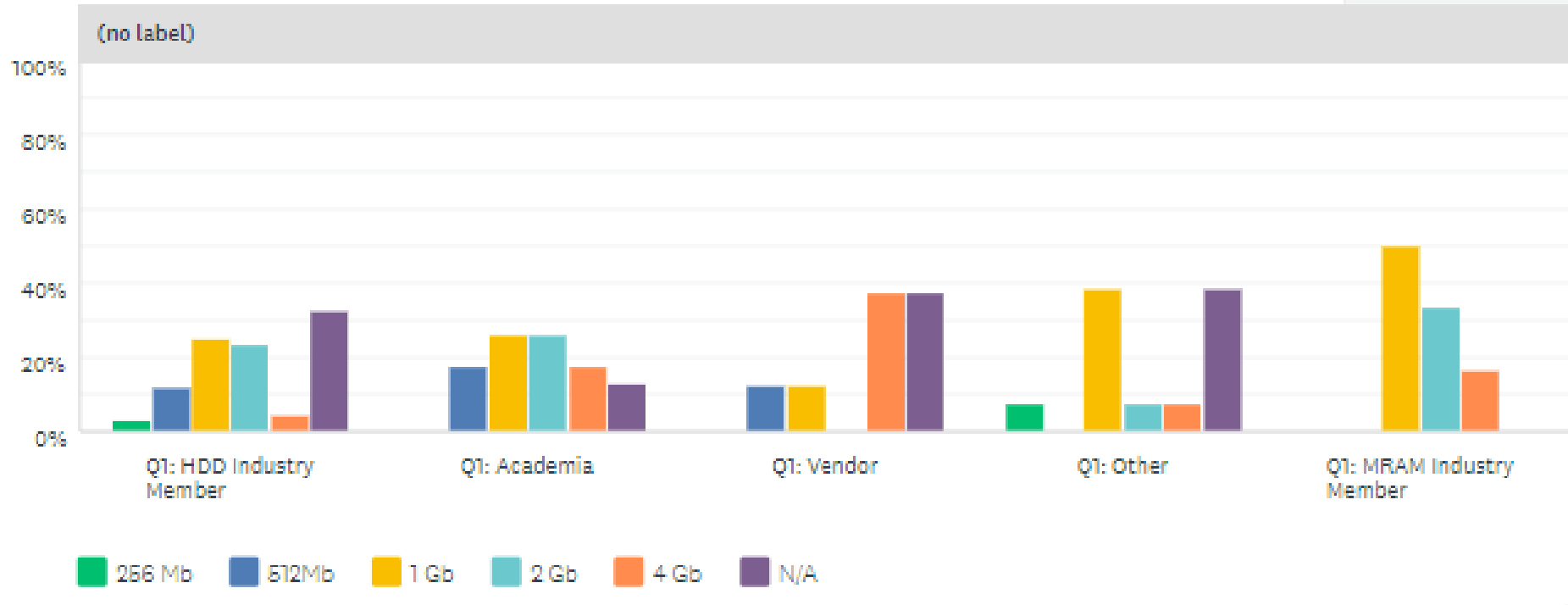
Even breakdown between 1Gb and 2 Gb by 2020.

Main fractional change is reduction in N/A

(was this influenced by Roadmaps shared in the meeting ?)

MRAM questions: Stand Alone capacity

(Pre and Post- due to high “N/A” counts)



MRAM favors 1 Gb, but low counts

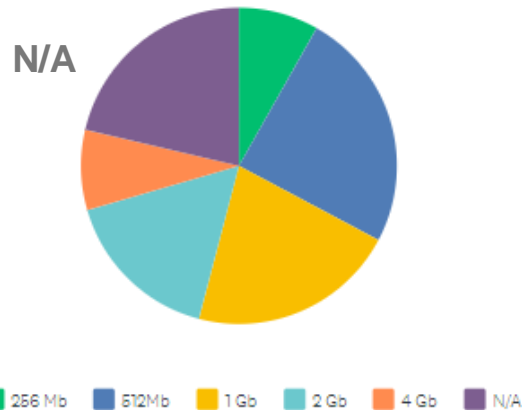
	256 MB	512MB	1 GB	2 GB	4 GB	N/A	TOTAL	WEIGHTED AVERAGE
Q1: HDD Industry Member	2.94% 2	11.76% 8	25.00% 17	23.53% 16	4.41% 3	32.35% 22	57.63% 68	4.22
Q1: Academia	0.00% 0	17.39% 4	26.09% 6	26.09% 6	17.39% 4	13.04% 3	19.49% 23	4.50
Q1: Vendor	0.00% 0	12.50% 1	12.50% 1	0.00% 0	37.50% 3	37.50% 3	6.78% 8	5.00
Q1: Other	7.69% 1	0.00% 0	38.46% 5	7.69% 1	7.69% 1	38.46% 5	11.02% 13	4.13
Q1: MRAM Industry Member	0.00% 0	0.00% 0	50.00% 3	33.33% 2	16.67% 1	0.00% 0	5.08% 6	4.67

New MRAM Question this year

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

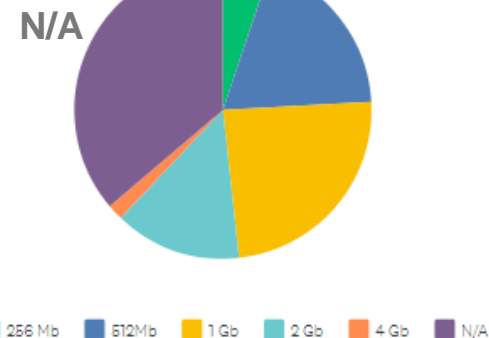
Answered: 61 Skipped: 4

Post-conference



	256 MB	512MB	1 GB	2 GB	4 GB	N/A	TOTAL	WEIGHTED AVERAGE
(no label)	8.20% 5	24.59% 15	21.31% 13	16.39% 10	8.20% 5	21.31% 13	61	3.56

Pre-conference

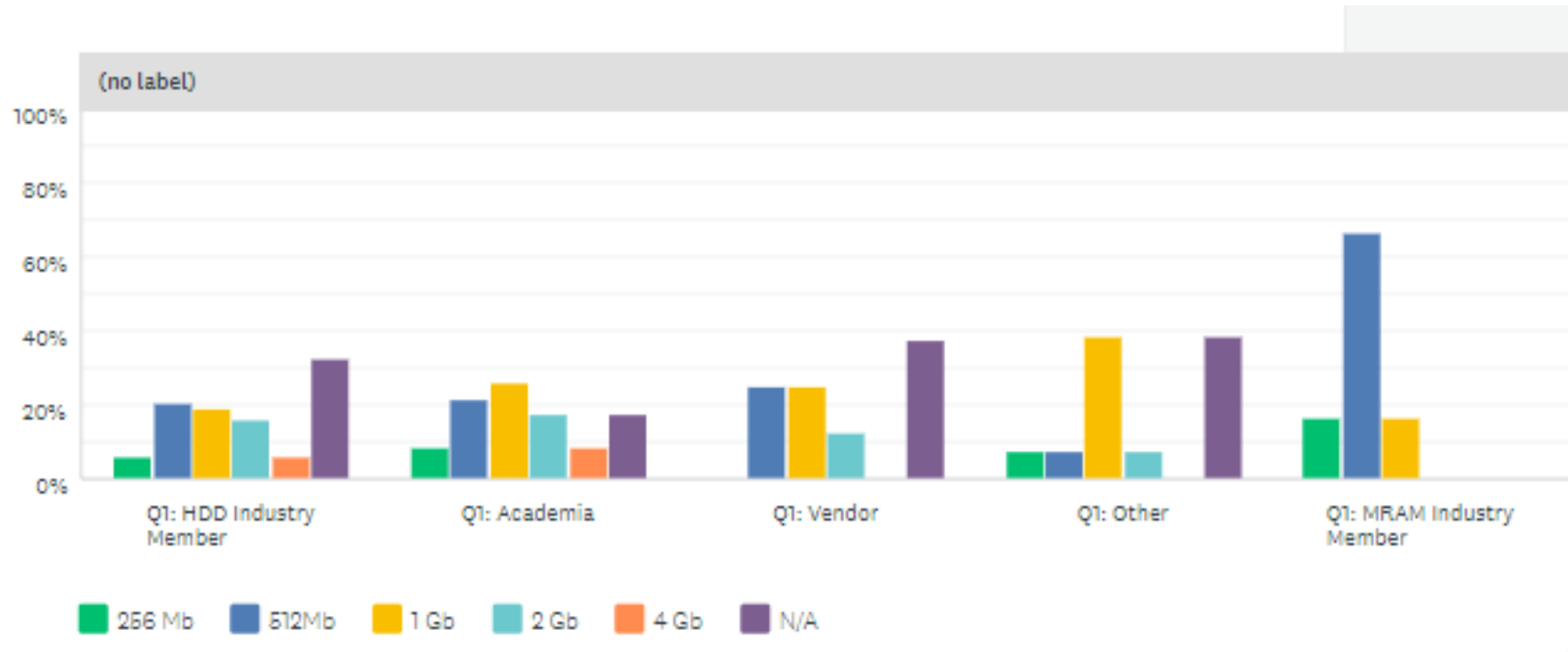


Between 512 Mb and 1 Gb is the favored response.

	256 MB	512MB	1 GB	2 GB	4 GB	N/A	TOTAL	WEIGHTED AVERAGE
(no label)	5.17% 3	18.97% 11	24.14% 14	13.79% 8	1.72% 1	36.21% 21	58	3.97

MRAM questions: Embedded Capacity

(Pre and Post due to high “N/A” counts)



MRAM favors 512 Mb Clearly

(no label)								
	256 MB	512MB	1 GB	2 GB	4 GB	N/A	TOTAL	WEIGHTED AVERAGE
Q1: HDD Industry Member	5.88% 4	20.59% 14	19.12% 13	16.18% 11	5.88% 4	32.35% 22	57.63% 68	3.93
Q1: Academia	8.70% 2	21.74% 5	26.09% 6	17.39% 4	8.70% 2	17.39% 4	19.49% 23	3.48
Q1: Vendor	0.00% 0	25.00% 2	25.00% 2	12.50% 1	0.00% 0	37.50% 3	6.78% 8	4.00
Q1: Other	7.69% 1	7.69% 1	38.46% 5	7.69% 1	0.00% 0	38.46% 5	11.02% 13	4.00
Q1: MRAM Industry Member	16.67% 1	66.67% 4	16.67% 1	0.00% 0	0.00% 0	0.00% 0	5.08% 6	2.00

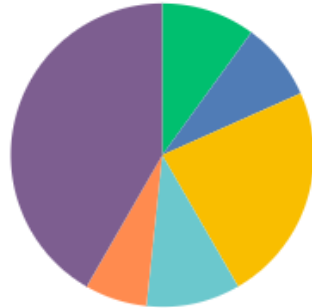
NAND capacity per chip

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

Answered: 60 Skipped: 5

N/A

Post-conference



1000 Gb 2000 Gb 3000 Gb 5000 Gb 10,000 Gb N/A

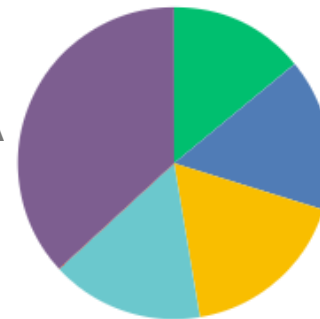
	1000 GB	2000 GB	3000 GB	5000 GB	10,000 GB	N/A	TOTAL
(no label)	10.00% 6	8.33% 5	23.33% 14	10.00% 6	6.67% 4	41.67% 25	60

Expected NAND capacity (Gigabits) per chip in 2020?

12

Pre-conference

N/A



1000 Gb 2000 Gb 3000 Gb 5000 Gb 10,000 Gb N/A

	1000 GB	2000 GB	3000 GB	5000 GB	10,000 GB	N/A	TOTAL
(no label)	14.04% 8	15.79% 9	17.54% 10	15.79% 9	0.00% 0	36.84% 21	57

Small difference in pre-post conference responses.
Majority opinion = 3000 Gb.

Caveat: (After George Box)

*All models are wrong
but some are useful*



George E.P. Box

*All surveys are wrong,
but some are useful*



Thank You

