USING NATURAL SERVICE AND ESTROUS SYNCHRONIZATION: HOW TO BE SUCCESSFUL

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Introduction

The U.S. beef cattle industry contains three segments relative to the breeding herd. Approximately 77% of operations are commercial, 6% are seedstock and 17% are a combination of commercial and seedstock (NAHMS, 2020). Overall, natural service is the most common strategy to generate pregnancies, as 90.7% of all females were exposed only to bulls (NAHMS, 2020). For producers with replacement heifers and cows bred to calve in 2017, 89.1% and 97% exposed these heifers and cows only to bulls, respectively (NAHMS, 2020).

Overall adoption of reproductive technology appears to have been slow, as evidenced by only 37.5% of operations using at least one technology. Slightly greater than 7% of producers employ estrus synchronization, 11.6% use artificial insemination (AI), and less than 20% have the semen of natural service bulls evaluated (NAHMS, 2020).

Breeding strategies using natural service and estrus synchronized females offer the producer the opportunity of shifting pregnancy initiation and calving to earlier in the breeding and calving seasons, resulting in greater weaning weights (Larson et al., 2010). Further, heifers that calve earlier have greater herd longevity and produce more pounds of calf during their lifetime than heifers calving later (Cushman et al., 2013).

Bull Breeding Soundness Evaluation

A breeding soundness evaluation (BSE) is a critical management strategy to ensure optimal health and promotion of fertility. A BSE should be performed on all natural service bulls: 1) prior to purchase, 2) annually, and 3) whenever there is concern relative to the potential fertility of a bull. Comprehensive guidelines for the BSE were updated by the Society for Theriogenology in 2018 (Koziol and Armstrong, 2018).

In 2020 NAHMS reported nearly 67% of beef operations surveyed "semen tested" bulls, while 57% measured scrotal circumference. No data, however, was provided regarding the use of a complete BSE. As described below, the BSE is a comprehensive evaluation and consists of three sections:

1) Physical examination. For natural service to be successful, bulls must be able to identify cows in heat and copulate. Consequently, the BSE begins with a physical examination of the bull, with particular importance paid to the soundness of eyes, feet and legs. Vision plays a key role in identifying potentially receptive females (Geary and Reeves, 1992). In order for copulation to occur, the bull must be able to physically support a large portion of his weight on his rear legs, fully extend his penis, and gain adequate intromission to deliver the ejaculate. Bulls with sore feet, legs or back, or with traumatic injuries, may not adequately or efficiently service cows. In addition, bulls with poor conformation (post-legged or sickle-hocked) have an increased risk of lameness compared with bulls of proper conformation. The BSE also includes examining the testes, epididymides, penis, and prepuce, as well as internal organs (seminal vesicles, prostate, and ampullae).

2) Scrotal circumference. Scrotal circumference is a measure of testicular volume and is highly correlated to sperm production, especially in young bulls (Willet and Ohms, 1957; Hahn et al., 1969). Consequently, bulls with insufficient scrotal circumference (relative to age) may not efficiently generate pregnancies. Increased scrotal circumference is associated with decreased age at puberty in related females (Brinks et al., 1978). An earlier age at puberty for beef heifers is associated with increased lifetime fertility and pounds of calf produced (Brinks, 1994). Veterinarians and producers must also realize, however, that scrotal circumference is of less value as an indicator of sperm production in bulls greater than 5 years of age, as there is a reduction in sperm output per gram of testis in old bulls (Hahn et al., 1969).

3) Semen collection and evaluation. Following collection of a semen sample (usually by electroejaculation), sperm motility and morphology are evaluated. In general, fertile bulls have a greater percentage of progressively motile sperm and a lower percentage of morphologically abnormal sperm than sub-fertile or infertile bulls (Williams and Savage, 1925; Lagerlof, 1934; Saacke, 1982; Barth and Oko, 1989).

Based on data resulting from a BSE, bulls may be classified as: 1) a satisfactory potential breeder, 2) an unsatisfactory potential breeder, or 3) classification deferred. A bull must meet minimum criteria for scrotal circumference, sperm motility and morphology to be classified as a satisfactory potential breeder. These bulls must also be free of other problems (feet, legs, eyes, penile, preputial, accessory sex glands) that may reduce fertility in natural mating situations.

The classification of a bull as a satisfactory potential breeder ***does not guarantee*** the bull is currently a satisfactory breeder, or that the bull will be a satisfactory breeder in the future. The BSE outlines minimum standards that must be achieved, in addition to passing a physical exam. A BSE does not evaluate a bull’s libido, a highly desirable and measurable trait. Libido is most often evaluated through the use of serving capacity tests that evaluate the number of services attempted by bulls during a limited period of time using restrained, non-estrual cows at predetermined bull: cow ratios (Blockey, 1976).

Bulls with physical abnormalities, and (or) those bulls not meeting the required minimum standards should be classified as an unsatisfactory potential breeder. Classification may be deferred at the discretion of the veterinarian for bulls that cannot be classified as satisfactory but may improve with time. This category includes young bulls with immature ejaculates and any bull with unacceptable sperm motility and morphology, considered to be temporary, and capable of improving. Sperm production (spermatogenesis) is a continuous, dynamic process that takes 61 days to complete. Consequently, physiologically stressful events (e.g., illness or environmental heat stress) may affect sperm motility and morphology for nearly two months after the event. Therefore, bulls that receive a "classification deferred" status on a BSE (due to poor sperm motility and morphology) should be re-tested in 60 days.

The importance of using BSE's cannot be overemphasized. In 2018, Roberts reported 82% of beef bulls from 2,883 BSE's conducted over 10 years (2007-2017) were classified as satisfactory potential breeders, with 15% deferred and 3% unsatisfactory. Carson and Wenzel (1995) evaluated 1,276 beef and dairy bulls and reported 37.1% received unsatisfactory (28.9%) or deferred (8.2%) classification. The main reasons cited for unsatisfactory or deferred classification were unacceptable sperm morphology, insufficient scrotal circumference, and physical problems, including eye lesions, lameness, and internal and external sex organ lesions. This gives evidence of the superiority of the BSE as compared to semen testing for the evaluation of breeding soundness.

Menegassi et al. (2011) reported a benefit/cost ratio of $19.67 for each $1 invested in the BSE. Similarly, Chenoweth (2002) argued a benefit/cost ratio of $20.00 for each $1 invested in the BSE. Using these values as a starting point, coupled with the realization that greater than 30% of beef operations surveyed did not "semen test" bulls, let alone have a BSE performed on bulls used for natural service (NAHMS, 2020), the BSE is clearly a prudent, yet underappreciated and underutilized economic tool.

Bull to Female Ratio

Briefly, recommendations for the bull to female ratio in non-synchronized animals is 1:10 to 1:60 (Perry et al., 2010). This range in the bull to female ratio depends on the age, experience, libido, and semen quality of the bull (Perry et al., 2010). The terrain and size of the breeding pasture must also be considered. Rupp et al. (1977) reported no differences in pregnancy rates between a bull to female ratio of 1:25 and 1:60 in the first 21 days of the breeding season provided the bulls were highly fertile and had a large scrotal circumference.

Management must consider the serving capacity of a bull when using natural service with synchronized females. Healy et al. (1993) reported a tendency for pregnancy rates over a 28-day breeding season to be reduced when a bull to synchronized female ratio of 1:50 (77%) was used compared to 1:16 (84%)(Table 1). No difference was reported between a bull to synchronized female ratio of 1:16 (84%) and 1:25 (83%) (Healy et al., 1993;Table 1). The range in age of bulls was 2 to 5 years old and all bulls had prior breeding experience (Healy et al., 1993). Net revenue per heifer exposed was optimized at a bull: heifer ratio of 1:25 (Table 1).

Table 1. Bull to heifer ratio, pregnancy rate, and net revenue per heifer exposed (Healy et al.,1993)

	Bull: heifer ratio		
	1:50	1:25	1:16
Bulls in pasture, n	2	4	6
Heifers in pasture, n	100	100	100
28 d pregnancy rate, %	77.0[a]	83.0	84.0[b]
Net revenue per heifer exposed	$955	$973	$965

[a,b]Values within a row with different superscripts differ ($P < 0.05$).

A reasonable recommendation of a bull: female ratio is 1:25. It is important to remember, however, that young bulls should be used at a lower bull to female ratio than older bulls. NAHMS (2020) data provides evidence that the average number of females per bull varies by herd size and age of the bull (Table 2).

Table 2. Average number of females expected to be serviced per bull, by bull type and herd size (NAHMS, 2020)

	Herd Size			
	Small (1-49)	Medium (50-199)	Large (200 +)	All
Yearling < 2 yr. of age, %	13.9	16.9	19.8	15.2
Mature > 2 yr. of age, %	20.3	26.5	27.7	22.0

Monitoring bulls during the breeding season is very important, as poor performance of a bull in a single-sire breeding group will affect the number of calves born from that group. In multiple sire breeding pastures, it is difficult to identify the sire of calves. For example, Van Eenennaam et al. (2007) investigated the paternity of 625 calves that resulted from a multiple sire (n = 27) breeding pasture. Following DNA analysis, Van Eenennaam et al. (2007) reported 5 of 27 sires produced over 50% of the calves. Further complicating the issue was the reality that 10 sires produced no progeny (9 of which were yearling bulls). Following genotyping, Abell et al. (2017) also reported large differences existed between bulls siring the greatest and least number of calves in a study with 179 bulls and over 3,700 calves. The majority of U.S. beef operations, however, do not conduct DNA testing for sire identification of calves (Table 3).

Table 3. Percentage of U.S. beef operations that used commercially available DNA testing for sire identification of calves (NAHMS, 2020)

	Herd Size			
	Small (1-49)	Medium (50-199)	Large (200 +)	All
Yes, %	2.6	5.6	10.6	3.6
N/A (Only 1 bull), %	20.8	8.8	1.4	17.3
No, %	76.6	85.6	88.0	79.0
Total	100.0	100.0	100.0	100.0

Lehrer et al. (1977) reported similar results to Van Eenennaam et al. (2007) when studying multiple sire breeding groups. Reasons for the variability in the number of calves born per bull in multiple sire groups may be related to libido (discussed later in this paper), social dominance, and fertility differences among bulls (Whitworth et al., 2008; Smith et al., 1981).

Social rankings are related to age and size, and a bull's rank may influence the number of females a sire is willing or able to breed (Table 4). Thus, special attention should be paid to sires that have decreased semen quality (borderline motility and morphology) and small scrotal circumference but appear to be socially dominant. These bulls could prevent a more fertile, but less dominant bull from breeding females. A bull's seniority is the major factor influencing his social ranking, with the dominant bull in a breeding cadre likely being an older bull (Chenoweth, 1997). When bulls (1 to 7 years of age) were used at a ratio of 1:7 to 1:51, yearling bulls had the lowest pregnancy rates (30.2%, based on number of females exhibiting estrus) compared to 2-yr old (40.3%) and mature bulls (3 years and older; 50.7%), even though pregnancy rate was not affected by bull to female ratio or number of females exhibiting estrus (Pexton et al., 1990).

Producers should avoid placing young and older bulls in the same multiple sire pasture. If multiple sire groups are necessary with bulls of mixed ages, bulls may be grouped together before the breeding season to allow for social hierarchy to form before interaction with females. If at all possible, it is advantageous to separate cows into single sire groups, or smaller multiple sire groups.

Table 4. Percentage calf crop sired by individual sires in multiple sire pasture (Lehrer et al., 1977)

	Percentage Calf Crop Sired				
Social Rank	Pasture 1	Pasture 2	Pasture 3	Pasture 4	Pasture 5
Bull 1	30%	34%	44%	92%	75%
Bull 2	21%	29%	18%	3%	25%
Bull 3	12%	21%	16%	3%	0%
Bull 4	10%	6%	4%		
Bull 5	9%	4%	4%		
Bull 6	9%	1%	4%		
Bull 7	5%	1%	2%		
Bull 8			2%		
Bull 9			2%		
Bull 10			0%		
Number of calves born	73	64	43	28	32

In multiple-sire breeding groups, bulls tend to breed or try to breed the same sexually responsive females (Farin et al., 1982). This can lead to females being bred by more than one bull and increases the risk of injury to a bull. When multiple cows or heifers are in estrus at the same time, they form a sexually active group. This grouping together increases the ability of a dominant (but possibly less fertile) bull to keep subordinate bulls from breeding cows. When single- versus multiple-sire use was compared in synchronized beef heifers (1:20 vs 2:40), mating performance of bulls and pregnancy rates were not different, but heifers in single-sire herds were serviced more times than those in multiple-sire herds (4.1 vs 2.6, respectively)(Farin et al., 1982), and pregnancy rates increased when females were serviced two or more times compared to females only serviced once (Pexton et al., 1990).

Estrous Synchronization and Natural Service

Estrous synchronization simply implies the manipulation of heifers and(or)cows to cause them to exhibit standing estrus around the same time. This can greatly reduce the number of days needed to detect a group of animals in standing estrus, and it allows for more females to conceive early in the breeding season. More specifically, estrous synchronization provides two chances to conceive within the first month of the breeding season.

Selection of a Protocol for use with Natural Service

Recommended protocols for use with natural service are shown in Figure 1. Unlike synchronization when using AI where the goal is to have the maximum number of females in estrus in the shortest period of time, synchronization for natural service must consider the limitations of breeding with natural service (serving capacity of the bull). Thus, protocols that distribute estrus over a period of 7 to 14 days are more advantageous. Therefore, it is necessary to understand how different synchronization products work with the physiology of the estrous cycle.

Prostaglandin $F_{2\alpha}$ (PG) regresses the corpus luteum (CL) and allows cows and heifers to return to standing estrus (Lauderdale, 1972; Rowson et al., 1972; Tervit et al., 1973) before they would normally return on their own. During the first five days after an animal exhibits estrus, the CL is not responsive to PG (Lauderdale, 1972; Rowson et al., 1972), but when administered between day 5 to 17, the CL will regress and the animal will usually exhibit standing estrus within 120 hours (Lauderdale et al., 1974). If a heifer or a cow does not have a CL (postpartum anestrus cows or prepubertal heifers), they will not respond. Thus, animals must be cycling, and be between days 5 and 17 of the estrous cycle to respond to PG.

Progestins (including exogenous progesterone and melengestrol acetate, MGA) which mimic progesterone produced by the CL to inhibit estrus and ovulation, are an effective method of synchronizing ovulation in cattle (Odde, 1990) by extending the luteal phase of the estrous cycle. After removal of the progestin, progesterone concentrations decrease and standing estrus and ovulation will occur. For example, when estrus is inhibited for 7 days, the normal 21-day estrous cycle of a herd is reduced to 14 days. A negative effect of synchronization with a progestin, however, is when a CL regresses and cows or heifers are exposed to a progestin to inhibit ovulation of the dominant follicle. In this scenario the follicle continues to grow and becomes a persistent follicle. Breeding animals at the first estrus after exposure to a progestin for more than seven days resulted in decreased fertility (Mihm et al., 1994; Ahmad et al., 1995) but subsequent ovulations had normal fertility (Odde, 1990).

When a controlled internal drug releasing device (CIDR) containing progesterone was inserted seven days before the start of the breeding season and removed the day the bull was introduced

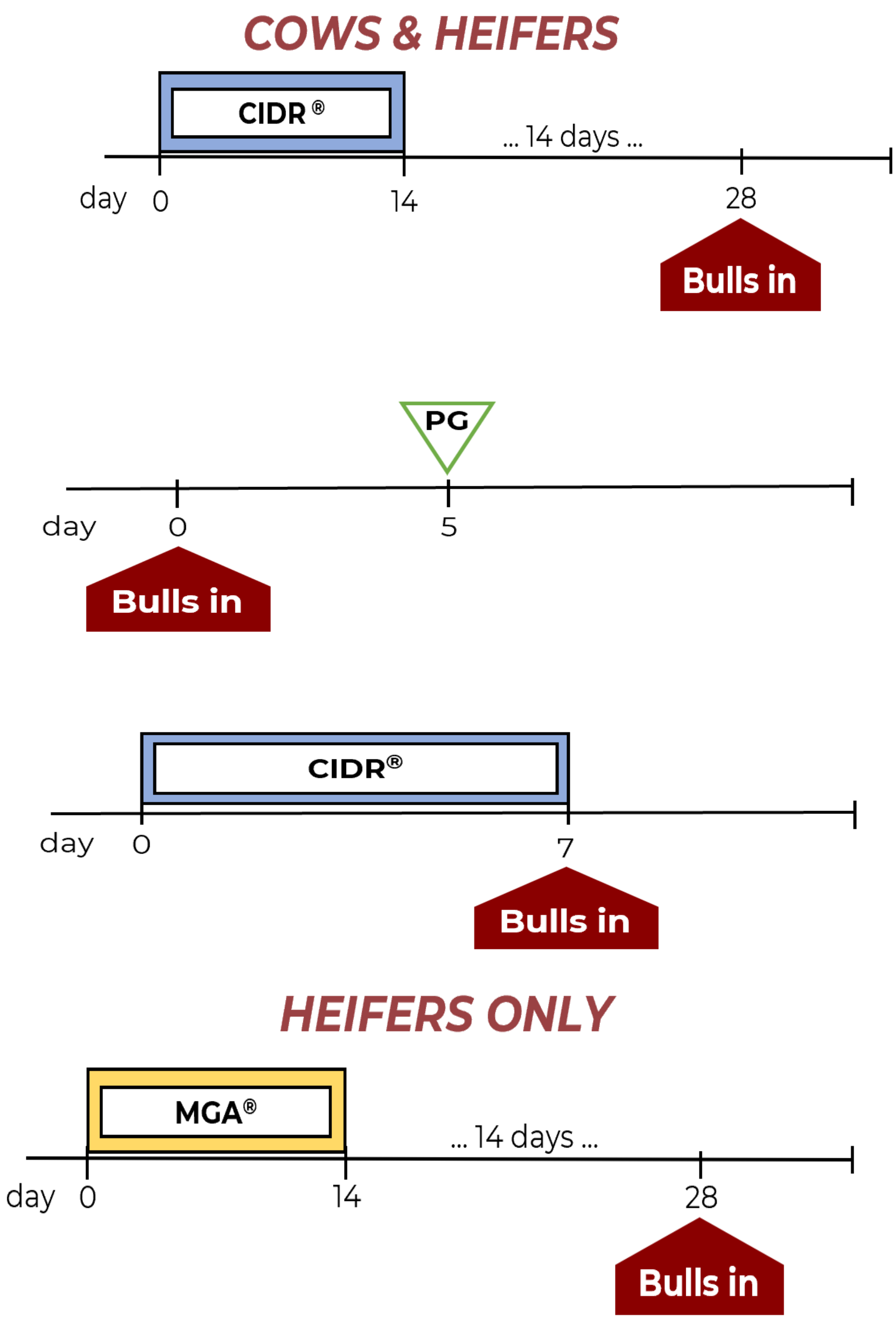

Figure 1: Recommended protocols for synchronizing cows and heifers to be bred by natural service.

(no injections), more CIDR-treated cows (43%) became pregnant by day 10 compared to non-synchronized cows (35%) (Lamb et al., 2008). However, when a single injection of PG was administered to a group of anestrous cows, no difference was detected between synchronized and non-synchronized cows (13.6% and 22.7%, respectively) (Whittier et al., 1991). Therefore, progestin-based estrous synchronization protocols capable of inducing puberty and shortening the postpartum anestrous period can result in a greater percentage of cows having a chance to become pregnant during the first few days of the breeding season. Unfortunately, not all progestins are equally effective at inducing estrous cycles in postpartum anestrous cows. Fewer anestrous cows treated with MGA (0.5 mg MGA•cow-1•d-1 for 7 days) ovulated compared to progesterone-treated (1.9 g of progesterone contained in a CIDR for 6 days) cows (33% and 91%, respectively)(Perry et al., 2004). Furthermore, fewer control (cows that spontaneously initiated estrous cycles; 23%) and MGA-treated anestrous cows (46%) exhibited normal length luteal phases compared to progesterone-treated cows (100%) (Smith et al., 1987; Perry et al., 2004). By day 22 after treatment withdrawal, however, there was no difference between the percentage of CIDR-treated cows that had ovulated (91%) and the percentage of MGA-treated cows that had ovulated (61%; Perry et al., 2004).

Referring to Figure 1, a single injection of PG on day 5 of the breeding season resulted in more cycling cows becoming pregnant between days 5 to 9 of the breeding season compared to cycling cows not treated with PG (55.7% vs. 25.0% respectively; Whittier et al., 1991). These results provide evidence of the greatest benefit of estrous synchronization, i.e., the ability to increase pregnancy rates early in the breeding season (Table 5), resulting in an increased number of calves born at the start of the calving season.

Table 5. Comparison between synchronized and non-synchronized pregnancy rates of cows and heifers bred by natural service

				Pregnancy Rate		
Study	Period of bull exposure	Cows or heifers	Synchronization method	Anestrual	Unknown	Estrual
Whittier et al. (1991)	4 days	Cows	1 shot PG	13.6%		55.7%[a]
			Not synchronized	22.7%		25.0%[b]
Lamb et al. (2008)	10 days	Cows	CIDR		43%[a]	
			Not synchronized		35%[c]	
Landivar et al. (1985)	80 hours	Cows	1 shot PG		19%	
	21 days		Not synchronized		33%	
Whittier et al. (1991)	25 days	Cows	1 shot PG		59.1%	
	21 days		Not synchronized		59.1%	
Lamb et al. (2008)	30 days	Cows	CIDR	64.4%		86.1%
			Not synchronized	64.7%		76.3%
Locke et al. (2020)	21 days	Heifers	14-day CIDR	52%		55%
			14-day MGA	53%		59%
Locke et al. (2020)	61 days	Heifers	14-day CIDR	57%		80%
			14-day MGA	66%		90%

Pregnancy rates within a study and estrous cycling status having different superscripts are different $^{ab}P < 0.01$; $^{ac}P < 0.05$

In another study, a CIDR was inserted for seven days and removed the day bulls were introduced to cows (no injections were given; Figure 1; Lamb et al., 2008). The use of a CIDR to synchronize with natural service decreased the average days to conception and also increased the percentage of animals that conceived in the first 10 days of the breeding season (35.9% vs 30.8%, Lamb et al., 2008).

Estrous Detection and Libido

For successful insemination of cattle to occur, animals must be detected in standing estrus. Detecting standing estrus (also referred to as heat detection or detecting standing heat) is simply looking for the changes in animal behavior associated with a cow or heifer standing to be mounted by a bull or another cow or heifer. With natural service, estrous detection is often considered to be easy, as it is "the bull's job." However, differences in estrous detection exist among bulls. Libido refers to a bull's desire to mate. Libido is thought to be a moderately inherited trait (Chenoweth, 1981; Blockey, 1989; Boyd et al., 1989) with heritability ranging as high as 0.59 (Blockey, 1989). This is because there is more variation in libido between sons of different sires than between sons of the same sire. It is important to remember that scrotal circumference, semen quality, and physical conformation (all important aspects of the Breeding Soundness Evaluation) are not related to libido (Blockey, 1975; Chenoweth et al., 1977), but libido has a direct effect on pregnancy rate and, as such, it can influence the success of an entire breeding season. Libido can be practically evaluated by closely watching a bull after introduction into a herd and determining his desire to detect cows and(or) heifers in estrus.

Summary

Estrous synchronization allows for more females to conceive early in the breeding season and gives females that do not conceive to the first service an opportunity for a second service within the first 30 days of the breeding season. When cows are synchronized, the number of animals that exhibit estrus in a short period of time is increased and considerations need to be made to ensure a bull is fertile and can cover as many females as possible. A protocol that distributes estrus over 7 to 14 days is ideal to not overwork a bull. A breeding soundness examination is the most common method to determine if a bull is producing fertile semen. With synchronized females, it is important to remember that mature bulls (3 years old or older) have increased efficiency in getting cows pregnant compared to younger bulls, and the use of multiple sires in a pasture offers some protection if a bull gets injured, but in multi-sire pastures, there is a definite social hierarchy that occurs. This leads to one sire breeding the majority of cows. When single- versus multiple-sire pastures were compared, mating performance and pregnancy rates did not differ, but heifers in single-sire groups were serviced more times than those in multiple-sire groups, and pregnancy rates increased when females were serviced two or more times compared to females only serviced once. No difference was detected in pregnancy rates between a bull to female ratio of 1:16 and 1:25, but pregnancy rates tended to decrease at a ratio of 1:50. When a protocol that is recommended for natural service is used, and mature, fertile bulls are placed with the estrous synchronized females, a successful breeding season with a large proportion of the herd conceiving early in the breeding season is achieved.

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